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The Form and Constitution of the Earth (*Retiring President's Address*) *L. B. Stewart* 1

The Motions of the Stars - - - - - *C. A. Chant* 21

A Question of Priority in Originating a Very Important Astronomical Method - - - - - - - *John E. McGrath* 36

Meetings of the Society

Annual Meeting at Toronto, Secretary's Report. *J. R. C.* 41

At Toronto - - - - - - *L. G.* 51

At Ottawa - - - - - - *R. E. DeL.* 54

At Hamilton - - - - - - *T. H. W.* 63

At Peterborough - - - - - *D. B. M.* 65

At Winnipeg - - - - - - *C. E. B.* 66

Notes from the Meteorological Service

Report of the Weather in Canada, December-January *R. F. S.* 67

Earthquake Records at Toronto and at Victoria, B. C. *J. V.* 71

Earthquake of February 10th - - - - *R. F. S.* 72

Magnetic Observations - - - - *R. F. S.* 74

New Observatory of Victoria, B.C. - - *R. F. S.* 75

Astronomical Notes

The History of the Cape Observatory - - 77

A New Algol-Type Variable in Pegasus - 77

The Lunar Crater Eimmart - - - 77

The Study of the Stars - - - - - *J. R. C.* 78

Notes and Queries - - - - - - *C. A. C.* 79

High Cosmic Velocities - - - - 81

Dr. Watson's Volume of Poems - - 82

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THE FORM AND CONSTITUTION OF THE EARTH.

BY LOUIS B. STEWART

(RETIRING PRESIDENT'S ADDRESS, ANNUAL MEETING, JANUARY 13, 1914.)

THE beginnings of astronomy probably date from the earliest development of the human intellect ; and that it should be the oldest of the sciences need not be a matter for surprise when we consider the striking and interesting nature of its phenomena, and the numerous services which it renders to mankind. Among the many questions requiring answers that would present themselves to a thoughtful observer possibly one of the first was that of the form and magnitude of our earth.

To a spectator placed upon an eminence the earth, as far as it could be seen, appeared as a level plain, after making due allowance for minor inequalities, so that primitive man regarded the earth as flat, surrounded by an otherwise shoreless ocean. The sun at setting plunged beneath this ocean, to reappear at the opposite side of the horizon at rising the following day. To allow for his passage beneath the earth it was conceived that the latter was supported by pillars between which the sun passed

during his nightly journey. Thus the Greeks explained the motion of the sun, and they claimed that they were indebted to the Egyptians for their astronomical knowledge.

The teaching of the Hindoos was even more fanciful than that of the Greeks. They taught that the earth is in the form of a hemisphere resting with its flat surface on the backs of four elephants, which in their turn stood upon the back of a gigantic tortoise. The question: What supports the tortoise? received the answer: The endless ocean. The too curious inquirer who wished to know what supports the ocean, was met with the reply that it extends all the way to the bottom. As there is no statement that has come down to us concerning the nature of the bottom or to what it is indebted for its support, we must infer that the last answer stifled all further inquiry.

Leaving these fanciful theories, we find that in comparatively early times more correct views as to the form of the earth were held by some philosophers, based no doubt upon the reports of phenomena observed by mariners and travellers, who found that the highest promontories disappeared from view as they drew away from the land; that a ship gradually vanished below the horizon in a manner that precluded the idea of a flat earth; that the sea horizon always appears circular. These and other phenomena, such as the varying meridian attitudes of stars as one travels in a north or south direction, must have given rise to a belief in the curvature of the earth in the minds of early astronomers. Thales, and after him Aristotle, is said to have taught the sphericity of the earth, and it is not surprising that we soon find attempts being made to determine its dimensions.

To Eratosthenes is due the honour of being the first, of whom we have any record, to make an estimate of the circumference of the earth based upon measurement. He was born at Syene, in S. Egypt, in the year 276 B.C., and his ability being early recognised by Ptolemy Euergetes he was placed by him in charge of the Alexandrine library. His geodetic measures consisted in noting that at Syene, at the time of the summer solstice, the sun passed through the zenith of the place, as was shown by

a vertical object casting no shadow ; while at the same time at Alexandria such an object cast a shadow of such a length as to show that the sun's rays made an angle with the vertical equal to one-fiftieth of a whole circumference. He concluded then that as the two places were nearly on the same meridian the distance between them is one-fiftieth of the whole circumference of the earth. The distance being estimated at 5000 stadia, the circumference of the earth becomes 250,000 stadia. As we do not know the precise length of his stadium we are unable to estimate the accuracy of this determination. We now know that the longitudes of the two places differed by 3° ; also the amplitude of his arc was too small by 15′. Notwithstanding these sources of inaccuracy, however, great credit is due to him for inaugurating a correct method for determining the dimensions of the earth.

Cleomedes, to whom we are indebted for the account of Eratosthenes' operations, suggested that if two gnomons be set up at two places on the same meridian the lengths of their shadows on the same day would serve to determine the amplitude of the arc joining the places. His suggestion thus contained the germ of the method used at the present day to measure the length of a meridian arc.

According to the same writer another determination of the earth's circumference was made by Posidonius about a century and a half later. This observer noticed that at Rhodes the bright star Canopus just appeared in the horizon when at meridian passage, while at Alexandria it had an attitude equal to one-forty-eighth of a circumference. As the distance between the two places was estimated to be 5000 stadia, the whole circumference becomes 240,000 stadia.

From this time interest in the sciences in Egypt and Greece appears to have languished, and during the dark ages the only country in which astronomical science was cultivated appears to have been Arabia. In the year 814 an Arabian caliph proposed to his astronomers the problem of measuring an arc of the meridian. From a selected spot on the plain of Singar near the Arabian

Gulf, one party was dispatched northward and another southward, each with instructions to measure as they went and continue their work until the altitude of the pole was observed to have changed by 1°. The northern party found 56 miles, and the southern party 56⅔ miles as the length of 1°. The English equivalent of the latter value, which was accepted as being the most accurate, is about 71 miles.

It was not until the 16th century that Europe, having awakened from the lethargy of the dark ages to new intellectual life, entered upon the era of development of which we have not yet seen the end. Among the various activities in which this newly found energy sought an outlet may be noted the exploration of foreign lands. America had been discovered; and in 1521 Magellan had completed the circumnavigation of the globe; and it may have been this latter achievement that turned men's attention to the problem of determining the earth's dimensions.

In 1525 Jean Fernel, court physician to Henry II. of France, and a cultivator of the mathematical sciences, measured the length of a meridian arc near Paris. His method was so crude as to be but a slight advance upon those of the ancient astronomers which have already been considered. He measured the length of his arc by counting the revolutions of a carriage wheel while driving from one end of it to the other; and his astronomical observations were made with a triangle used as a quadrant. He found the length of 1° to be 365,088 feet, a result very near the truth.

It is not proposed to give an exhaustive account of all the geodetic surveys of the last three centuries, but only to notice briefly those that embodied some improvement in method, or were important in their results.

A great advance upon previous methods was now for the first time made by Snellius, who employed the method of triangulation to measure the length of a meridian arc, the method which has been in use ever since, and is superior to all others on account of its accuracy and cheapness, combined with adaptabil-

ity to any country whatever its nature. He measured a base with a chain between Leyden and Soeterwood, and his chain of triangles, 33 in number, extended from Alcmaar to Bergen-op-Zoom. This distance, projected upon a meridian, gave a meridian arc having an amplitude of 1° 11′ 05″ which made the length of 1° to be 55074 toises, a toise being equal to 6·3946 English feet. His angles were measured with a graduated semi-circle 3½ feet in diameter, and his latitudes observed with a quadrant 5½ feet in diameter, neither of these instruments being provided with a vernier or telescope sight, as neither had been invented at that time. It was not to be expected under those circumstances that his result would be remarkable for precision in spite of the precautions which he took to secure it; in fact his length of a degree is in error by about 2000 toises. Though his triangles were solved as plane triangles, neglecting spherical excess, the labour involved in their solution will be realized when we remember that at that time logarithms had not been invented.

The first attempt at degree measurement in England was made by Norwood about 1635. He measured with a chain the distance from London to York, occasionally, however, resorting to pacing, and determined his latitudes by observing altitudes of the sun on the same day, June 11th, in the years 1633 and 1635. His adoption of Fernel's method instead of following in the path marked out by Snellius, is to be regarded as a retrograde step, in spite of the fact that his value of a degree 367,176 feet, or 57420 toises, is so near the truth. Its accuracy, however, must have been the result of a compensation of errors.

Another improvement was now introduced by Picard who used in 1669 telescope sights on his angle-measuring instrument. He measured a base line with wooden rods of 5663 toises, and a base of verification of length 3902 toises, and his triangulation extended from Malvoisine, near Paris, to Sourdon near Amiens. His result for the length of 1° was 57060 toises.

Picard's work was rendered famous in another way, in that it furnished Newton with data by which he was enabled to establish the law of universal gravitation. About 1665, when

he had retired from Cambridge to his home at Woolsthorpe on account of the great plague, his thoughts were first turned to the subject of gravity. Reasoning from Kepler's laws he readily proved that the planets are kept in their orbits by an attractive force directed to the sun whose intensity varies inversely as the square of the distance. It at once occurred to him that if this law is universal it must be in virtue of it that the moon is retained in her orbit about the earth ; that the distance through which the moon falls towards the earth, or is deflected from a tangent to her orbit, in a unit of time stands in a simple relation to that through which a body falls in the same time near the earth's surface.

To be more explicit — the distance through which a body falls in a given time varies directly as the attractive force and the square of the time. The moon's distance is 60 radii of the earth, therefore the force of the earth's attraction acting upon it is only 1/3600 of its value at the earth's surface, so that the moon falls in one second only 1/3600 as far as a body at the earth's surface. In one minute, or 60 seconds, it will fall 3600 times as far as in one second, therefore the moon should fall as far in one minute as a body near the earth's surface falls in one second, or 16 feet.

Newton, however, by assuming 60 miles to a degree, the value used by navigators at that time, found only 14 feet for that quantity. He considered, therefore, the discrepancy a proof of the inaccurancy of the law of the inverse square, and laid aside for the time his investigations in that direction. In January, 1672, at a meeting of the Royal Society, the result of Picard's work was mentioned, giving 69·1 miles as the length of a degree, and Newton was able to revise his calculations, with the result that his hypothesis was amply verified. This is generally supposed to have led to the publication of the *Principia*, which laid the foundation of gravitational astronomy, though some affirm that Newton delayed the publication of his great work until he had proved that a spherical body attracts an outside body as if all of its matter were concentrated at its centre.

Up to this time the size of the earth had been investigated on the supposition that its form is spherical, and that it is therefore only necessary to measure the length of a degree on its surface in order to determine its dimensions. A discovery was made, however, by Richer (1672) which turned the attention of astronomers to the possibility that its form may deviate materially from that of a sphere. He had been sent by the Academy of Sciences of Paris to the Island of Cayenne to make certain astronomical determinations, and while there he found that his clock, which had been regulated in Paris to keep correct time, lost about 2½ minutes daily, so that it was necessary to shorten the pendulum by 1¼ lines to make it beat seconds. His report was received with doubt until confirmed by the subsequent observations of Halley, Varin, and Deshayes on the coast of Africa and America. The phenomenon was first explained by Newton in the third book of the *Principia*, where he shewed that it is the result of a decrease in the force of gravity in the neighborhood of the equator due to increased distance from the centre of the earth combined with the effect of centrifugal force. He also investigated the figure of the earth and showed that it must be an oblate spheroid. As a consequence of this the lengths of the degrees of latitude must increase with the latitude.

Between the years 1684 and 1718, Picard's triangulation was extended by J. and D. Cassini southwards as far as Collioure and northwards to Dunkirk, making a total amplitude of 8° 31′. The northern portion of the arc, having an amplitude of 2° 12′, gave 56960 toises as the length of a degree, while the southern portion gave 57097 toises. These results seemed to negative the theoretical conclusions reached by Newton in the *Principia*, and to point to the prolate spheroid as representing the true form of the earth. A heated controversy arose in consequence, and in the excitement thus occasioned, as well as from a desire to know the truth of the matter, the Academy of Sciences resolved to apply a crucial test of the rival theories by measuring a meridian arc at the equator and another at the Arctic Circle.

Two parties were accordingly organized; one, composed of

Maupertius, Clairaut, Camus, Le Monnier, the Abbé Outhier, and Celsius, being commissioned to measure an arc in Lapland; and the other, composed of Godin, Bouguer, and de la Condamine, a meridian arc in Peru.

The polar party landed at the town of Tornea at the mouth of the river of the same name in the beginning of July, 1736. They began by exploring the river, and finding that the course of its valley is nearly north and south and flanked on either side by high mountains, they resolved to establish the stations of their triangulation on these mountains. The tops had to be cleared of timber, and the signals were constructed in the form of cones composed of several large trees denuded of their bark, their white surfaces being thus visible at a distance of 10 or 12 leagues. The angles were measured with a quadrant having a radius of 2 feet, whose accuracy they verified by measuring all the angles at a station that close the horizon. The three angles of each triangle were also measured, and also check angles, which were sums or differences of necessary angles at a station.

The measurement of the angles occupied 63 days, and on September 9th the party reached Kittis, the most northerly station, and made preparations for their astronomical work. Two small observatories were built, one of which contained a small transit instrument and a clock, the former instrument being set up exactly over the centre of the station. The transit instrument was used in determining time and the azimuths of the two stations visible from the observing station. The other observatory contained a zenith sector having a telescope 9 feet in length which was used in determining the difference of the latitude of the two terminal stations. Observations of δ Draconis, which passed near the zenith of the place, were taken between October 4th and 10th. The party then proceeded to Tornea and commenced observations on the same star on November 1st, finishing on the 5th. Their instrument gave the difference of zenith distance of the star as observed at the two stations; this difference, corrected for aberration, precession and nutation, gave the amplitude of the arc 57′ 26″·93.

The final operation was now the measurement of the base line. This had been intentionally postponed until winter, as its site had been so chosen that the greater part of its length lay along the river Tornea, its extremities only being on land. The frozen river would thus afford a level surface upon which to carry on their measurement. The party had brought with them from Paris a standard toise — called afterwards the "Toise of the North" — which with another taken by the Peruvian party, had been carefully adjusted to be at standard length at 14° Reaumer. By careful comparison with this standard they prepared eight wooden rods each five toises in length and terminating in metal studs, which were used in measuring the base.

This work was begun on December 21st, the party having been divided into two, each taking four rods and working independently, the rods probably being laid upon the snow with their ends in contact. The difference between the measurements was only 4 inches in a length of 7406·86 toises.

It only remained now to compute the length of the meridian arc contained between the parallels of the two terminal stations. This was found to be 55023·5 toises.

Seeing that the resulting length of a degree would be far in excess of that in the latitude of Paris they submitted their work to a rigid examination. An investigation of the division errors of the arc of their sector was made, and the amplitude of their arc re-determined, increasing it to 57′ 30″·42. Observations for azimuth were made at Tornea, and it was found that the resulting azimuth differed by 34″ from the value computed through the triangulation from the observations at Kittis; but this would have but a trifling effect upon the length of the meridian arc.

Their final value for the length of a degree was 57437·9 toises.

Meanwhile the Peruvian party had selected as the scene of their operations the valley in which Quito is situated, and which lies between the double range of mountains into which the Andes are there divided. By placing the stations of their triangulation alternately on opposite sides of the valley they were able to

form extremely well-conditioned triangles, though the labor involved in occupying the stations may be inferred from the fact that seven of them were situated at heights exceeding 14,000 feet. A base line was measured near each extremity of their chain of triangles, the northern base being near Quito, and having a length of 7·6 miles, and the southern base a length of 6·4 miles. In their astronomical work they observed the absolute zenith distances of stars, thus finding the latitudes of their terminal stations, and not merely their difference of latitude. The same stars, however, were observed at the two stations, so that their difference of latitude was unaffected by errors in the star places.

The amplitude of their arc was 3° 07′ 01″, and its length 176945 toises, thus giving 56753 toises as the length of 1° at the equator, which was about 685 toises shorter than the value found in Lapland, the length of a degree in France being intermediate between these.

Thus was it demonstrated finally that the form of the earth is that of an oblate spheroid, and subsequent arc measurements have only served to confirm this conclusion.

The problem that now presented itself was the determination with all possible precision of the exact dimensions of the terrestrial spheroid. Geodetic surveys were soon in progress in every civilized country.

On representations from Count Cassini de Thuri to the Royal Society of London of the advantages that would be derived from the extension of the French triangle chain into England, the British Ordnance Survey was begun in 1784, and by 1851 the whole of the British Isles was covered with a network of triangles. This triangulation, however, as in the cases of all modern surveys, was designed to serve the double purpose of arc measurement, and also as the basis of an accurate topographic survey.

The year 1791 saw the inception of the grandest project ever devised for the establishment of a standard of length. Certain prominent members of the Academy of Sciences, among whom were Laplace and Lagrange, proposed to the Constituent

Assembly of France — and received their sanction — that the ten-millionth part of the earth's meridian quadrant be adopted as the national standard of length, to be called the metre. It was further proposed that this length be determined by the measurement of a meridian arc extending from Dunkirk to Barcelona, and comprising 9° 40′ of latitude. This was accordingly carried out, the work being intrusted to Legendre and Mechain, and the length of the arc was found to be 551584·7 toises, and its amplitude 9° 40′ 25″.

The commission appointed to revise their calculations, and to determine the length of the meridian quadrant, combined this new French arc with the Peruvian arc, and thus found for the length of the meridian quadrant 5,130,766 toises, which gave as the length of the metre 0·5130763 in parts of the toise of Peru.

It would be impossible even to notice briefly all the arc measurements that were now made in different countries, each contributing its quota to the growing mass of data for determining the earth's figure. It is sufficient to state that in 1799 Laplace made a determination of the elements of the spheroid based upon a discussion of nine meridian arcs measured in Lapland, Holland, France, Austria, Italy, Pennsylvania, Peru, and at the Cape of Good Hope. In this discussion Laplace made use of the expression

$$d = A + B \sin^2\phi$$

which gives the length of a degree of the meridian in a given latitude, A and B being functions of the semi-axes. As only two such equations are necessary in order to determine the two unknowns some principle had to be assumed in order to obtain the best values from all the measurements. Laplace adopted the principle that the unknowns should be determined so as to fulfil the conditions that when substituted in the observation equations they should make the algebraic sum of the errors in d equal to zero, and their sum, when all are taken positively, a minimum. This gave the expression

$$d = 56753 + 613{\cdot}1 \sin^2\phi$$

for finding the length of a degree in any given latitude. On applying this expression to the Lapland arc, however, it was found to give a value 138 toises shorter than that found by observation, from which Laplace concluded that the earth deviates considerably from the spheroidal form. It must be mentioned on the other hand that in 1801 an expedition was sent from Stockholm in charge of Svanberg with instructions to re-measure the Lapland arc, with the result that he found for the length of 1° a value about 200 toises less than that found by Maupertius, thus conforming more closely to the value given by Laplace's empirical formula.

During the 19th century geodetic work was carried on vigorously by every civilized nation, and great improvements were introduced in instruments and methods. The result of this activity is that we now have the following arcs available for investigating the earth's figure: The British-French arc extending from the Shetland Isles through France into Africa, and covering 27° 01′ of latitude; the Russian arc, extending from the Danube to the North Sea, and having an amplitude of 25° 20′; the arc of the parallel in latitude 52° extending from the west coast of Ireland to the Ural Mountains and embracing 68° 55′ of longitude: the arc lately measured in Spitzbergen between latitudes 76° 38′ and 80° 50′ N., which is important on account of its high northern latitude; the Indian arcs, including 24 meridian arcs and 7 arcs of parallels of latitude; the S. African arc; the Peruvian arc, lately re-measured; the American oblique arc following the Atlantic coast for a distance of 1623 miles; the western oblique arc extending along the Pacific coast; the arc of the parallel of latitude 39° N., extending from the Atlantic to the Pacific; the 98th meridian arc, now well under way, and to which Canada and Mexico have been invited to contribute their shares, and which, when complete, will extend over 50° of latitude.

A proposal made by Sir David Gill should be here mentioned. When director of the Royal Observatory at Cape Town he instituted the project of extending the S. African triangulation

through Natal, and then on through the whole extent of the African continent, following the meridian of 30° of E. longitude, to Cairo, and thence on to connect with the Russian arc on the Black Sea. This arc will have a total amplitude of 105°.

The application of the electric telegraph to longitude determination has given measurements of arcs of parallels of latitude an importance in these investigations fully equal to that of meridian arc measurements.

As additional data became available investigations were made from time to time to determine the spheroid that would best represent the measured arcs. The most important of these were those made by Bessel in 1841; Col. A. R. Clarke, of the British Ordnance Survey in 1866; and another in 1880; and Helmert in 1887. Clarke in 1866 also investigated the dimensions of the earth regarded as an ellipsoid having three unequal axis, using the same data as in determining the spheroid, and, as was to be expected, it satisfied the observations better than the spheroid. The compression of the equator — which on this assumption is an ellipse of small eccentricity — was thus found to be 1/3281, and the longitude of one extremity of its major axis 15° 31′ E. Another similar investigation made by Clarke in 1878 reduced the compression of the equator to 1/13706 and made the longitude of an extremity of its major axis 8° 15′ W. The fact that the use of additional data diminished the eccentricity of the equator is perhaps significant, shewing that, disregarding local irregularities, the earth probably departs but little from the spheroidal form.

It must not be inferred, however, that any spheroid or ellipsoid could ever be found that will exactly represent all observations. There will always be differences between the computed or geodetic positions of points and those found by astronomical observation greatly in excess of the errors of observation. These differences arise from deviations in the direction of the plumb line due to local irregularities of density of the matter composing the earth's crust.

An important improvement in the method of investigating

the form of the earth was recently made by J. F. Hayford, of the United States geodetic survey, using the data of that survey alone. He made use of 507 astronomical observations of latitude, longitude, and azimuth, connected with their triangulations, and allowed for the attraction of the earth's crust on the assumption that the condition termed "isostasy" exists at a depth of 114 kilometres. Three different assumptions of depth were made, but this gave the best results. His values were:

$$a = 6378283 \text{ metres}, \epsilon = 1:297{\cdot}8$$

The following is a tabular statement of some of the determinations of the elements of the terrestrial spheroid made during the 19th century, and to date:

Year	By Whom	ϵ	Length of Meridian Quadrant
1806	Delambre	1 : 334	10 000 000
1819	Walbeck	1 : 302·8	10 000 268
1830	Schmidt	1 : 297·5	10 000 075
1831	Airy	1 : 299·3	10 000 970
1841	Bessel	1 : 299·2	10 000 856
1856	Clarke	1 : 298·1	10 001 515
1863	Pratt	1 : 295·3	10 001 924
1866	Clarke	1 : 295	10 001 887
1868	Fischer	1 : 288·5	10 001 714
1872	Listing	1 : 289	10 000 218
1878	Jordan	1 : 286·5	10 000 681
1880	Clarke	1 : 293·5	10 001 869
1887	Helmert	1 : 299·15	10 002 041
1906	Hayford	1 : 297·8	

In addition to the method of determining the earth's figure by geodetic measurements there are others that must be considered briefly. Foremost among these is the method by pendulum experiments. In 1743 Clairaut published his work on the figure of the earth, which contains a remarkable theorem shewing a connection between the force of gravity at a point on the earth's surface in given latitude and the compression of the earth. The part played by the pendulum in the application of this method is the determination of the force of gravity, as the time of oscillation of a pendulum varies directly as the square root of its length,

and inversely as the square root of the force of the earth's attraction. If then the time of vibration of a pendulum of a known length be observed, the value of the force of gravity follows.

Since 1808 pendulum experiments have been made in various parts of the world ranging from the southern hemisphere to Greenland and Spitzbergen. In 1901, by a discussion of about 1400 observations of g made during the 19th century, Helmert obtained the value of the compression 1 : 298·3.

Other methods of finding this quantity, which are purely astronomical, are by lunar perturbations and lunar parallax. There are certain disturbances of the moon's motion that are caused by the earth's spheroidal figure, and their expressions are therefore in terms of the compression. If then the amount of the lunar perturbations is found by observation the compression of the earth can be found from it. The value found in this way is 1:297·8.

Observations of lunar parallax may also be employed for this purpose, whether made by the meridian method or the diurnal method. Sir David Gill has lately advocated the use of this latter method. He considered that if all the observatories situated not too far from the equator were to co-operate in taking systematic observations of the moon a very precise value of the compression could be found.

To sum up: it is probable that the final values of the major semi-axis and the compression of the elliptic meridian will be found to differ but little from the quantities:

$$a = 6378200$$
$$c = 1 : 298$$

To return to the term "isostasy" — this condition may be defined as follows: Imagine a spheroid concentric with the terrestrial spheroid and whose surface is everywhere about 76 miles within that of the latter, then the pressure on all parts of the surface of this inner spheroid, due to the weight of the superincumbent crust, is the same. In other words, all prismatic columns of the earth's crust having the same cross-section

and extending from the surface down to the isostatic surface — as it may be termed — have the same mass. Hayford's investigations shew that geodesy furnishes positive proof of the existence of isostasy, and places the isostatic surface at a depth of 76 miles, and shews moreover that that depth is almost certainly not less than 62 miles, nor greater than 87 miles.

Pendulum experiments also shew that there is a deficiency of gravitating matter beneath mountain ranges and table lands, and an excess near the seashore. This has been especially observable in India, where at elevated points near the Himalayas the value of the force of gravity has been found to be the same as it would have been if there were no intervening mountain mass between the point of observation and sea level. On the other hand, in the neighborhood of the Indian Ocean an excess of attracting matter was revealed. Facts like these first led Archdeacon Pratt to suspect the existence of isostasy.

We see, however, various agencies at work on the earth's surface that must tend to disturb this isostatic condition. Mountains are being worn down by the action of water and their materials transported to lower elevations, and there deposited. If, then, this state of isostasy is maintained, it must be effected by a counter flow of material in the opposite direction somewhere below the surface. Geology furnishes evidence that this takes place by the fact that in spite of rapid denudation mountain regions are often observed to maintain their elevation, as if they were raised from below as fast as they are torn down from above. Also sedimentary rocks of great thickness, such as the Palæozoic formations of the Appalachian region, contain shallow water fossils throughout, shewing that the sea bottom must have sunk as fast as sediment was piled upon it. Similar examples occur in many other localities.

On the theory of isostasy the interior portion of our globe, within the layer of compensation is composed of material of the same density at equal distances from the centre — or rather, the layers of equal density are concentric spheroids. The theory that the crust of the earth is only a few miles in thickness, and

rests upon an intensely heated molten interior, is no longer tenable. It is now known that the earth as a whole possesses a high degree of effective rigidity, as great as if it were composed throughout of steel. It is no doubt true that the interior of the earth is in an intensely heated condition and that it appears to possess some of the properties of a fluid ; at the same time it behaves in many respects as a solid.

A heated and therefore cooling body like the earth must shrink ; and thus its solid outer crust would be continually under the necessity of adapting itself to a contracting interior. This would give rise to enormous tangential stresses in the crust to which it must eventually yield. That this has taken place in the past is evidenced by the plications and dislocations shewn in the rock strata that compose the crust ; and to the fact that it is still taking place is probably due the earthquake shocks that are of almost daily occurrence in some part of the world. It is practically certain that no earthquake centre has been situated at a greater depth than thirty miles below the earth's surface, and probably not below twenty miles, from which it would appear that any transfer of material that may occur at greater depths must take place without shock, and that consequently the material there must behave as a fluid.

The most valuable evidence regarding the earth's interior is afforded by the study of earthquake phenomena. An earthquake shock occurs in some part of the world, and at once elastic vibrations are set up in the surrounding material which are propagated in all directions from the centre of disturbance, and leave their records upon the seismographs installed at stations in various parts of the world. By a study of these records some important conclusions can be drawn.

In the first place it is found that the earthquake waves that reach stations within about 20° of the centre of disturbance are of an entirely different character from those observed at more distant stations. The former are confined to the earth's crust, while the latter travel through the earth by the shortest route,

or possibly by brachystochronic routes, or routes of shortest time. It is with the latter that we are chiefly concerned.

A study of a great mass of data regarding these long distance waves has revealed the following facts :

These waves may be divided into preliminary tremors — of which there are two phases, — and large waves. The time required for the waves of the first phase to travel from an earthquake centre to a distant station is proportional to the length of the chord drawn between those points. From this it may be inferred that these waves travel at a uniform rate along chords, that rate being about 9·25 km. per second. The times required for waves of the second phase to reach the distant stations are not proportional to the lengths of the chords, but shew a velocity increasing with the distance travelled according to some law not yet understood. The large waves are propagated along the surface of the earth, and have a uniform velocity of about 2·95 km. per second.

The generally accepted view regarding the preliminary tremors is that those of the first phase are longitudinal waves, while those of the second phase are transverse or distortional waves. As the velocity of propagation of a longitudinal wave varies as the square root of the ratio of the volume-elasticity to the density of the medium, it appears that, whatever the composition of the interior of the earth, the ratio of volume-elasticity to density must be constant at all depths, and therefore constant with varying density of the medium traversed. This is a property of gases. If the waves of the second phase are transverse waves it would appear that this same medium is capable of transmitting such waves, which cannot be transmitted by fluids or gases. Until the law of their increase of velocity with distance, and therefore with depth, is better understood, it is too soon to draw any conclusions regarding the nature of these waves, and of the medium by which they are transmitted.

Professor Nagaoka, of the University of Tokio, investigated the densities, elasticities, moduli of rigidity, and the velocities of transmission of longitudinal and transverse waves, for the vari-

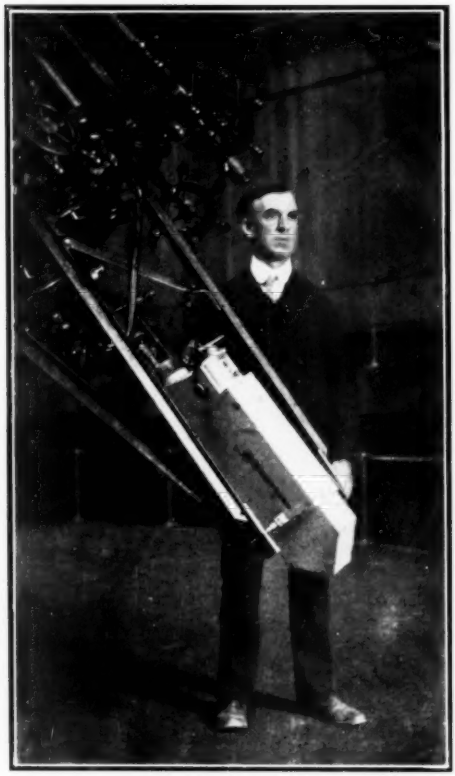
ous kinds of rock that compose the earth's crust. An important result is to shew that while there is a slight increase of density in going from the Quaternary to the Archæan rocks there is a large increase of elasticity, so that the rate of propagation of wave motion in the latter rocks is much greater than in the former, the velocities for longitudinal waves going as high as 6 and 7 km. per second. It may be stated here that the velocity in an unlimited medium of steel would be 6·2 km. per second. It might then be inferred that at great depths in the earth the ratio of elasticity to density may continue to increase with depth to a certain point, so as to permit of the great velocities of wave transmission observable in earthquake phenomena.

Professor Milne concludes from the velocities of seismic waves at different depths that the materials and general characters of the crust of the earth that are found at the surface may extend to a depth of about 30 miles, but beyond that the material seems rapidly to merge into a fairly homogeneous nucleus. This state probably extends to a depth of 6/10 of the radius, but the remaining 4/10 forms a core which differs in its physical, and possibly its chemical, constitution, from the outer portion. What the state of this nucleus is must be a matter largely of conjecture until we have a fuller knowledge of the state of matter when subjected to the vast pressures that must exist within the earth's interior.

Additional evidence that the earth as a whole is at least as rigid as steel is furnished by a study of tidal phenomena, and also by the variation of latitude. That bodily tides are caused by the moon in the solid earth has been proved by Hecker; and Sir George Darwin found by a study of the tides of long period at different ports, extending over an interval of 33 years, that the ocean tides are about $\frac{2}{3}$ as great as if the earth were unyielding. He also shewed that this is the ratio that theoretically should exist if the rigidity of the earth were that of steel.

With regard to the variation of latitude, Euler shewed that if the earth's axis of rotation and figure do not coincide one axis will revolve about the other in a period of 305 days. All

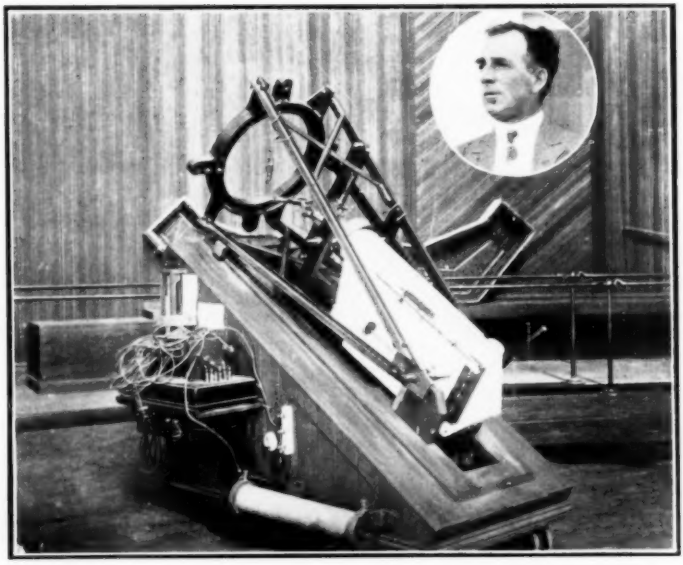
attempts to discover a periodicity in latitude variations, however, were futile until Chandler, by a study of a great mass of material, shewed that a period exists, but instead of 305 days he shewed a period of 427 days. It was then pointed out by Newcomb that Euler had assumed the earth to be perfectly rigid, and that by assuming its rigidity as equal to that of steel the period would become 457 days. The inference to be drawn from this evidence is that the earth is more rigid than steel.



DIRECTOR CAMPBELL AND THE MILLS SPECTROGRAPH

(In August, 1907, at the writer's request, Director Campbell stood beside the Mills Spectrograph and allowed this picture to be taken with a hand-camera).

PLATE II.



THE MILLS SPECTROGRAPH, DISMOUNTED

(The portrait is from a negative taken with a hand-camera in 1910).

THE MOTIONS OF THE STARS

By C. A. Chant

It is always gratifying to see a great project planned with forethought and vision, carried forward for years with ability and energy, and, after numerous obstacles have been overcome, ending in the complete realisation of the original aim. There is added pleasure if at the same time other unexpected and important objects are incidentally attained. Many such examples are to be found in the history of astronomy, but none of them more interesting or important than that which is the chief subject of Campbell's recent book on "Stellar Motions",*

The contents of this work were presented in a course of lectures at Yale University in January and February, 1910, though the book did not appear until the summer of 1913. These lectures comprised the seventh course in the series given on the Silliman Foundation, and it is safe to say that the subject and its treatment occupy a worthy place amongst those of the other distinguished lectures under the same aupices. Perhaps a brief review of the contents of the work may prove of interest.

The sub-title of the book indicates it general nature. The subject of spectroscopic astronomy is so recent and the author has had such a prominent part in its development that we feel an especial interest in the historical account given in the first chapters of the work. On page 9 is quoted Comte's famous declaration (1830), namely: "We shall never be able to study the chemical composition of the heavenly bodies; . . . . Our positive knowledge with regard to them will necessarily be limited to their geometrical and mechanical phenomena. It will be impossible, by any

*Stellar Motions, *with special reference to motions determined by the spectrograph*, by William Wallace Campbell, Sc.D., LL.D., Director of the Lick Observatory, University of California. *New Haven* and *London*, 1913.

means, to include investigations of their physical, chemical (and other) properties." Now in 1814-15 Fraunhofer had fully revealed the beautiful solar spectrum, furrowed with its numerous dark lines, and within thirty years after the publication of Comte's statement Kirchhoff gave to the world the fundamental principles of spectrum analysis, which were immediately applied to determine the physical structure and chemical nature of the stars. We should not be too 'positive' in our philosophy.

The fact that there is great diversity in the spectra of the heavenly bodies was also first demonstrated by Fraunhofer (1823); and the investigations of Rutherfurd, Secchi, Huggins, Pickering and others have aroused interesting and profound speculations. It is now generally believed that by means of their spectra we can trace the life history of the suns which people the depths of space. A concise but clear description of the various types of spectra is given towards the end of chapter I.

The effect of approach or recession of a light-source, such as a star, upon its spectrum was enunciated by Doppler in 1842 and by Fizeau in 1848, and upon Kirchhoff's announcement of his discovery it was seen that relative motion of the source and the observer should cause a displacement of the spectrum lines, which, if it could be measured, would allow us to deduce the speed with which the source is approaching towards or receding from us.

Between 1863 and 1887 observers of great ability in England and Germany made many attempts to measure visually displacements of the spectral lines but not one trustworthy result was obtained. In 1890, however, Keeler, who was an exceptionally capable observer, with the great Lick refractor, a superior spectroscope and the excellent atmospheric conditions prevailing on Mount Hamilton, succeeded in measuring the velocities of three bright stars. For Arcturus he found an approach of 6 kilometres per second, for Aldebaran a recession of 55 km. per sec. and for Betelgeuse a recession of 16 km. per sec. Later measurements have shown that these three values are substantially correct.

He also measured the velocities of fourteen nebulæ, finding them of magnitudes similar to those of the stars.

We are not surprised at the failure of visual observations. For a velocity of 10 km. (6 miles) relative to the observer, with a spectroscope of average dispersion, the displacement of the spectrum lines would amount to only $\frac{1}{2500}$ of an inch, a very small quantity to measure. But the application of photography changed all this ; and in chapter II. is given a concise outline of the development of the new method and of the modern radial velocity spectrograph, designed for a single special purpose.

Vogel and Scheiner, of the Royal Astrophysical Observatory, in Potsdam, Germany, were the first to attain decided success. In the years 1888 to 1891, using a 12-inch refractor, they obtained many photographs of spectra, devised methods of measuring them with precision and comparative ease, and published the velocities of 51 of the brighter stars. These results have been widely quoted in works of astronomy.

In 1895 Campbell's opportunity came. He was permitted by Professor Holden, Director of the Lick Observatory then, to use the 36-inch refractor three nights of the week for the measurement of stellar velocities by means of photography. The programme he planned was an ambitious one, namely, to measure the radial velocities of all stars as bright as the fifth magnitude whose spectra were suited for the purpose. From these results he aimed to determine with accuracy the direction of motion and the speed with which the solar system is moving through space, and perhaps to throw new light upon other great problems of the universe. As a matter of fact the by-products of the investigation have been of superlative interest and importance.

But it was necessary to have a suitable spectrograph and Mr. D. O. Mills, a member of James Lick's first board of trustees, agreed to supply the deficiency. The new instrument was designed by Campbell and constructed by Brashear. The most difficult conditions as to dispersion, rigidity and uniformity of temperature had to be met. Campbell remarks (p. 44) :

"A successful design is a bundle of fortunate compromises between the great number of conflicting interests. When the new instrument was attached to the telescope and submitted to exacting tests, most discouraging defects were encountered, especially in some of the optical parts. The spectrum was very imperfectly defined, and the greater part of a year was devoted to locating the difficulties, one by one, and in removing them. When the changes which seemed to be required had been incorporated, in 1896, and the spectrograph was put into commission, the spectra were beautifully defined, and the accuracy attained indeed surpassed expectations. Probable errors were reduced at once from 2·6 km. to half a km. per second for the brighter stars containing good lines, and down to nearly a quarter of a km. for bright stars containing the best quality of lines. What was still more important, systematic errors appeared to be of minute or vanishing size. One photograph with this instrument gave greater accuracy, depending on the character of the spectrum, than could be obtained from ten to fifty spectrograms made with its predecessors."

To make a survey of the entire sky it was necessary to establish an observatory in the southern hemisphere. This also was made possible by the liberality of Mr. Mills. Using his own experience gained in six years of constant observing, and acting on a suggestion by Wright that the instrument should be supported near its two ends, Campbell designed a new spectrograph to be attached to a 37-inch reflector which was finally located near Santiago, in Chile. This institution has proved very successful and is still in operation.

Next year, 1902, the new Mills spectroscope was constructed, with all the improvements which active experience could suggest, and this has been in continuous use on Mount Hamilton since May 1903. In obtaining the photographs of the spectra of some stars, exposures several hours long must sometimes be given, and under these circumstances the greatest foes to a good photograph are flexure of the large heavy instrument and change of temperature during the exposure. The former is avoided by the improved design and mounting, and the latter by an electrical heating device controlled automatically. For years little difficulty has been experienced in securing good spectrograms.

In order to measure and reduce the spectrograms new instruments and new methods had to be devised. These have now been almost standardised, and an account of the various advances,

many of them due to Campbell, are given in the first three chapters of the work. To render the account more complete the manner of deducing the various formulas used are given in foot-notes.

As the essence of the spectrographic determination of radial velocities is the measurement of wave-lengths, the astrophysicist must carefully consider the various conditions which affect wave-lengths. An interesting account of investigations made upon these matters is given at the end of chapter II. Some peculiarities in the wave-lengths in the sun's spectrum as compared to spectra produced in the laboratory were observed by Jewell of the Johns Hopkins University, and investigation has shown that a change in the pressure of the vapors surrounding a source of light will produce an apparent change of wave-lengths.

Discussing this matter Campbell remarks (p. 82) :—

"Our sun is believed to be an average-sized star. It may readily occur in stars vastly larger than our sun, that the pressures under which the lines are formed are greater than in the case of our sun; that the wave-lengths are greater, in consequence, than we assume them to be; and that resulting radial velocities based upon the assumed wave-lengths will be estimated slightly greater than they really are. For stars less massive than our sun, on the contrary, the observed velocities may be smaller than they really are. However, it seems equally probable that the lines of the same element, in stars of widely varying masses but of the same spectral type, may be formed under essentially equal pressures in all, at the various depths in their atmospheres which equalise the pressure. It has not been found possible to test stellar spectra for this pressure by *direct* methods; our telescopes have had too little power to let us use the high dispersion required. It is hoped that the large reflecting telescope recently completed may be successfully applied to the problem."

Possibly the great reflector which Canada is soon to possess may assist in elucidating this difficult problem.

The changes in the lines due to the Zeeman effect are referred to, but though Hale has shown that there is a magnetic field about sun-spots (and his more recent work indicates that the sun as a whole has a magnetic field) it is not probable that any such effect will be detected in the distant stars.

The recent suggestion that light suffers dispersion in its pass-

age through interstellar space is also discussed. Nordmann and Tikhoff, independently and almost simultaneously, observing certain variable stars, became convinced that the minima of brightness occurred earlier if observed with the red portion of their light than when observed with the blue portion. Some very interesting evidence regarding this matter has been produced in connection with various stars, but it is contradictary or negative and we must await more detailed and more accurate results.

The application of the spectroscope to measure the rotation periods of members of the solar system is discussed in the earlier portion of Chapter III. The results on the rotation of the sun by Dunér in 1887-1901, as well as the more recent work at Edinburgh by Halm, and at Mount Wilson, chiefly by Adams, are in good agreement if we except those values obtained by the latter with the calcium line λ4227 and the hydrogen line *Hα*. The periods of rotation deduced from these are smaller and do not vary with the latitude as much as do those obtained otherwise. These remarkable results are referred to on page 92 : —

> The fact that the solar rotation period, derived from the sun spots and the ordinary Fraunhofer lines, increases with latitude is surprising enough, but that origins of observation in the higher atmospheric strata should have shorter and more constant periods than are yielded by the deeper strata is a mysterious fact, indeed. We can admire the exceedingly accurate measures upon which these rotation periods depend, but it is a question to what extent the apparent periods are real. It seems possible that factors at present unknown may be seriously influencing the spectrographic measures and preventing their correct interpretation.

It may be remarked that the elaborate and exhaustive investigations by Messrs. Plaskett and DeLury at Ottawa, published since the date of these lectures, fail to confirm Adams's results.

One of the most beautiful applications of the spectrograph was that made by Keeler, at Allegheny, in 1895, to analyse the system of Saturn. Using only a 13-inch telescope, in the smoky atmosphere of Pittsburgh, he obtained a complete confirmation of Maxwell's demonstration in 1867 that the rings must be a collection of small bodies revolving like so many tiny moons about the planet. One of the first pieces of work which

Campbell undertook with the Mills spectrograph was to confirm and to extend this magnificent work by Keeler. In this he was very successful, and in the volume (p. 101) is a reproduction of a spectrogram of Saturn (taken in 1909) showing the peculiar tilt of the lines from the ball and the rings, from which the conclusions as to rotational velocities are deduced.

The spectrograph has been applied successfully to Jupiter and Mars (and more recently by Slipher, of the Lowell Observatory, to Uranus), but the results with Venus are unfortunately contradictory, Belopolsky finding a short rotation period (22h.), and Slipher a long one — too long to be measured in this way.

The author gives an interesting calculation of the actual time required to make a spectrographic survey of all the stars down to the fifth visual magnitude. In the entire sky there are about 1600 such stars, of which 1100 are within reach of northern observers. The exposure time varies from a few minutes for a first magnitude star to 2½ hrs. for a fifth visual magnitude, the average being fully 1½ hrs. Six plates constitute an average night's work, from sunset to sunrise. If the telescope is available for this work three nights a week, there would be ninety usable nights per year. Four good spectrograms of each of the 1100 stars referred to would require from ten to twelve years for observation alone. The development, measurement and reduction of the plates would take three times as long, while the discovery of many spectroscopic binary stars has almost doubled the labor. From such statements as these one can appreciate in some degree the great labor and skill represented in the recent publication in a single *Bulletin*, by Director Campbell, of the radial velocities of 915 stars. At the time the lectures were given there were available, from observations made at Mount Hamilton and Santiago, the radial velocities of 1340 stars.

Towards the end of Chapter III. are some interesting results as to some special stars. In Table V. (p. 115) are given forty stars whose motions through space exceed 50 km. per second. The faint star *Groombridge* 1830 must have a speed of approximately 250 km. per second, while the southern star

Cordoba Zones 5^{h}243, (of magnitude 9·2, and to obtain a spectrogram of which 29 hrs., spread over four nights, were consumed) has a speed of approximately 260 km. per second. Arcturus, one of our finest stars, must have a speed of more than 150 km. per second.

These extraordinary velocities have caused the gravitational astronomers some anxiety. From no ordinary and reasonable hypothesis could Newcomb or Kelvin deduce from gravitational attraction alone velocities at all comparable to these.

Chapter IV. is devoted to the motion of our system through space, as determined by proper motions of the stars *i. e.* their apparent motions in a direction at right angles to the line joining the star to the observer; while in Chapter V. our motion as determined by the spectrograph is discussed. These chapters are exceptionally interesting.

From the proper motions of 13 stars Herschel in 1783 deduced the position of the Solar Apex, *i. e.*, the point in the sky towards which the sun's motion is directed. His result was R.A. 262°, Decl. 26° N., near the star λ Herculis. He thinks "that we have already some reasons to guess (*sic*) which way the solar system is probably tending its course." Campbell properly remarks: "That he came so close to the truth was not the result of a guess, but of the philosophical ability, amounting to real genius, with which he considered all known facts bearing upon the questions before him."

From this time onward many computations of the positions of the apex have been made, and a very clear and concise account of them is given, the recent results of Kapteyn and Kobold being discussed more fully. The striking work of Kapteyn, Eddington and others on "star streaming" or "star drifts", and its bearing on the position of the apex are discussed. After this follows an account of the distribution of the brighter stars, especially as given by Herschel, Seeliger and Pickering, and a reference is made to Mädler's argument that the entire stellar universe revolved about Alcyone, an idea which appealed to the imagination and which was widely circulated in popular scienti-

fic literature. "More complete studies of stellar motions showed that the idea is without foundation. In fact, the position of Alcyone, far outside the plane of the Milky Way, as a centre about which the myriads of stars in the Milky Way are in revolution, is sufficient to stamp the idea as absurd." (p. 162).

The determination of the solar motion by means of the radial motions of the stars is somewhat simpler and more direct than with proper motions, but the two methods are mutually supplementary. In 1901, using the radial velocities of 280 stars, Campbell deduced a velocity of 19·9 km. per sec. for the sun, and for the apex the position R.A. 277°·5, Decl. 20° N., which was somewhat farther south than most of the previously obtained results. This was attributed to the lack of velocities of southern stars. By 1910 the number of usable radial velocities had increased to 1047 spread over the entire sky. These were combined, for reasons given, into 172 groups of neighboring stars, and then by the method of least squares the following results were obtained:

POSITION OF SOLAR APEX, CAMPBELL 1910

R.A.,	272° 0′	2°·50
Decl.,	+ 27° 26′	3°·00
Vel.,	− 17·77 km.	0·62 km.

The smallness of the velocity as compared to that obtained in 1901 caused surprise, but other solutions with different grouping of the stars did not appreciably increase it. The position of the apex as just given agrees satisfactorily in R.A. with the best results from proper motions, but it is three or four degrees south from the proper-motion apex of greatest weight.

In connection with his account of this determination Campbell gives some interesting results regarding the motions of some groups of stars — especially the "Big Dipper" and the Pleiades.

As already remarked, the by-products of Campbell's work are of almost equal importance with the main result on the solar

motion : and in chapters VI., VII. and VIII. some of these are discussed.

One of the most remarkable results is that the radial velocity varies with the type of the star. The number of stars observed was so great that they could be arranged in classes and a comparison between the classes instituted. The conclusion is clear that the velocities of the stars are functions of their spectral types, that is, of their effective ages. Arranging the stars in classes, the progression of average velocity with advancing spectral type is clear and unmistakable.

The results are thus summarised (p. 207) :—

Spectral Classes	Number of Stars	Average Radial Velocities
O and B	141	8·99 km. per sec.
A	133	9·94 "
F	159	13·90 "
G and K	529	15·15 "
M	72	16·55 "
Nebulæ (Keeler)	13	23·4 "

In the table is given the radial velocity, which is, of course, but a component of the entire velocity. By the method of mean values it can be shown that the average *radial* velocity is only one-half the average *space* velocity, and hence to obtain the true velocities in space those given in the table should be doubled.

This would give for classes G and K a space velocity of 30·3 km. per second. Our sun belongs to this class, and as its velocity is only 18 km. per second, or 60 per cent. of the average, we must consider it one of the slow-moving stars.

The reason why the speed of the star depends on the stage of its development is certainly a mystery.

Concerning this Campbell remarks (p. 216) :

> It is not easy to explain why the velocities of the stars should increase with their effective ages, for we are accustomed to think of all matter as equally old gravitationally. Why should not the materials composing a nebula or a Class B star have been acted upon by gravitational forces as long and as effectively as the materials in the Class M stars? Are stellar materials in the ante-stellar state sub-

ject to Newton's law of gravitation? Does gravitation become effective only after the processes of combination are well under way? Is it possible that the gaseous matter composing a nebula is acted upon as effectively by radiation pressure as by gravitational attraction? The observed fact of the dependence of stellar velocity upon the spectral class is so new that these comments and questions make no pretensions to the status of a solution; but I am unable to suggest any other directions in which we should seek for an explanation.

This remarkable relation between class of star and velocity has been corroborated by others, especially by Boss, in considering the proper motions of the stars.

Referring to the great velocity attributed to nebulæ Campbell remarks (p. 207):—

> It was a surprise to find the average velocity of the thirteen nebulæ, as observed by Keeler, in excess of the averages for the stellar spectral types. This may or may not indicate that the number of nebulæ available is too small to serve as a basis for averages. If from the list of thirteen nebulæ we remove the Orion nebula, which has radial velocity nearly zero, the average residual radial velocity for the remaining twelve nebulæ is in excess of 25 km. Here we have evidence of great strength and importance, in support of a hypothesis that the planetary nebulæ have been formed from stars through processes arising from collisions with or close approaches to other massive bodies. The zero velocity of the Great Nebula in Orion is not out of harmony with the hypothesis.

In chapter VI. Campbell, following Kapteyn's practice, shows how the radial motions combined with proper motions may indicate the average parallax for a group of stars, and he gives the following results:—

PARALLAXES BY MAGNITUDES AND TYPES OF STARS

Visual Magnitude	Type I.	Type II.	Types I. and II.
2·51-3·50	″0·0076	″0·0157	″0·0133
3·51-4·50	0·0150	0·0169	0·0163
4·51-5·50	0·0147	0·0119	0·0125

In chapter VII. is given an account of visual and spectroscopic binary stars. The first discovery of a double star, Mizar, was made by Riccioli of Bologna in 1650. In 1665 Hooke by

accident found γ Arietis; Richaud discovered α Centauri in 1689 and Bradley, about 1750, noted Castor, γ Virginis, β Cygni and 61 Cygni. In 1776 Mayer of Mannheim made a serious search for doubles, which led to the discovery of 33 pairs; but the systematic search by Herschel, beginning in 1779, gave body and life to the subject. At first it was thought that the two components of the double were almost in line with the observer simply by accident, but at last the fact that they are physically connected systems and revolving about each other was appreciated. "Of the seven or eight thousand known double stars whose components are at this moment less than 5″ apart, and whose fainter components go down even to the thirteenth magnitude, it can scarcely be true that more than five pairs in the entire list are doubled merely as a projection effect." (p. 235).

Aitken and Hussey have found that one star in about 18 is a visual double.

The first spectroscopic binary, Mizar*, was discovered at Harvard, by Pickering, in 1889. A few months later the Harvard photographs revealed β Aurigæ to be of the same nature, and in the same year Vogel of Potsdam, discovered Spica. Since then the discoveries have multiplied rapidly and at present over 300 are known.

Campbell summarises thus (p. 245):—

> We may be sure, when we look at the stars, that at *least* one in five, on the average, is attended by a companion, invisible and of mass sufficiently great to swing the bright member of the system rapidly around in a large orbit..... Frost has made a specialty of measuring the radial velocities of those stars whose spectra are of the so-called Orion or helium type, known as Class B stars. He has found that one star in two and a half on his programme is a spectroscopic binary.

Interesting details of several binaries are given. In the case of α Centauri, where the visual orbit is well determined and the velocities of both components are measurable, the parallax can be determined spectrographically. It comes out 0·76 +

*The star which is a spectroscopic binary is one of the components of the visual double mentioned just above.

0″·02, which is in excellent agreement with that determined with the heliometer by Gill and Elkin, 0″·75 ± 0″·01. In 1889 the Mills spectrograph showed Capella to be a binary, the system as a whole receding from us at the rate of 30 km. a second. Campbell's study of Polaris (which was the first star observed with the Mills spectrograph — in 1896) shows that there are three bodies in the system. Two of the bodies revolve in a period of 4 days while these two revolve about the centre of mass of the entire system in 12 years.

In a series of tables Campbell arranges the elements of the binary systems according to spectral class, and Aitken tabulates information regarding visual binaries ; these are of great interest and importance but lack of space prevents a discussion of them at present.

The conclusion of this chapter is as follows (p. 281) :

> As the accuracy attainable improves with experience, the proportional number of spectroscopic binaries discovered will undoubtedly be enormously increased. There is a possibility that the stars attended by massive companions, rather than by small planets only, are in a decided majority ; suggesting, at least, that our solar system may prove to be an extreme type of system rather than of the prevailing or average type. This is not a casual and passing comment. We do not possess a shred of positive evidence that any other star than our own is attended by small planets ; we seem powerless at present to obtain any evidence in favor of or against their existence ; and the prevailing belief that planets exist in other systems rests upon analogy to the solar system. We *have* the evidence of visual and spectroscopic binary stars that other systems with two or more massive central bodies are extremely common.

The concluding chapter deals with variable stars and the solar parallax. The first variable star, Mira Ceti, was discovered in 1596 by Fabricius. Up to 1800 only 12 variables were known ; in 1865, 113 ; in 1888, 225 ; while now, chiefly by photographic methods at the Harvard College Observatory, the number has been increased to more than 3000.

Vogel, in 1890, applied the spectroscope to Algol. He found that at one-quarter period before each minimum of brilliancy Algol was receding from the solar system with a speed of

39 km. per second; and at one-quarter period after each minimum the star was approaching the solar system at the rate of 47 km. per second. From this it would appear that the system is approaching the sun at 4 km. per second, and the velocity of the bright body in its orbit, taken as circular, is 43 km. per second. The system has also been studied by Belopolsky and by Schlesinger and Curtiss, whose results are generally in good agreement with Vogel's.

There are two interesting classes of bright short-period variable stars known as "Cepheids" and "Geminids," of which δ Cephei and ζ Geminorum are, respectively, typical examples. In the former a shorter time is taken in rising to maximum than in falling to minimum; in the latter the reverse is the case. There are 53 in the two classes so far known, and eleven of these have been exhaustively investigated by the spectrograph, ten of them at the Lick Observatory. In every case the radial velocity was found to be variable, going through its cycle in the same time as the star's variability. This probably indicates that each is a binary; and in the case of every star investigated its maximum brilliancy is at or near the time of greatest approach to the solar system and its minimum brilliancy at or near the time when the bright star of the system has its greatest velocity of recession from the solar system.

> These are keys which give promise of unlocking many secrets of the Cepheids and Geminids. What can be more remarkable than that variable stars of this class should be at their brightest when they are moving rapidly towards the observer and at their faintest when they are moving rapidly away from him? (p. 306).

Many further results regarding variable stars obtained by the spectrograph are given, but I cannot refer to them.

In time the spectrograph may furnish the best determinations of the solar parallax. In 1892 Campbell suggested that by observing the radial velocity of a star in the morning and the evening at intervals of six months the orbital velocity of the earth could be obtained and the magnitudes of the orbits deduced. 1904–05 Küstner, of Bonn, from 18 spectrograms of Arcturus,

found for the parallax, $8''.844 \pm 0''.017$, while a determination at the Royal Observatory of the Cape of Good Hope from 302 stars gave $8''.800 \pm 0''.006$, which is in excellent agreement with that deduced from observations of Eros, namely, $8''.807 \pm 0''.003$, while the labor involved is very much smaller.

In the preceding pages I have referred to some of the subjects discussed by Dr. Campbell and have quoted his conclusions regarding various matters, but many things must be left unmentioned.

In the book are portraits of eleven astronomical worthies, views of the Lick Observatory and its South American station, as well as illustrations of various spectrographs and of the various kinds of spectra. All these are well printed, but they would have been better, in the writer's opinion, if good plate paper had been used.

I think the book a notable contribution to science, and as it offers important evidence upon some of our most profound problems, it cannot fail to exert great influence on astronomical thought.

A QUESTION OF PRIORITY IN ORIGINATING A VERY IMPORTANT ASTRONOMICAL METHOD

Rœmer or Horrebow?

A STUDY OF THEIR RESPECTIVE MERITS FOR HONOR OF ORIGINATING THE MODERN METHOD FOR EXACT DETERMINATION OF LATITUDES

By John E. McGrath

IN the extremely interesting paper by Mr. G. Van Biesbrœck, in Vol. VII, No. 5, *Journal of the Royal Astronomical Society of Canada*, September-October, 1913, wherein he reviews the extraordinary scientific achievements of the great Danish Astronomer and Physicist, Olæus Rœmer, it is contended that from the evidence in Rœmer's "Adversaria," published, in 1910, by the Royal Danish Society of Sciences and Letters, as a memorial of the bi-centenary of his death, justice demands that the method for determining latitude, generally known as the Horrebow-Talcott method, should be called the Rœmer-Talcott method.

The analysis of the "Adversaria" made by Messers Van Biesbrœck and Thebyghien, was crowned by the Royal Society, and the award to these authors of the gold medal offered as the prize for the best elucidation of the work, consequently, stamps their discussion as one of the highest authority; but this does not of necessity imply infallibility for all their conclusions; in support of which statement I submit here two notes from the report of the Committee which recommended the award of the medal of honor:

> "Quand l'auteur* dit dans son introduction que le manuscrit de Adversaria a été recemment decouvert par un heureux hasard, il se sert d'expressions trop fortes. Les editeurs disent seulement 'neglecta fere' il pour constater que le manuscrit n'est pas reste inconnue, on

*When the report was under consideration the dual authorship of the paper was not known to the Committee, hence the reference to "l'auteur."

peut se reporter à la revue — *Nordisk Universitats Tidsskrift*, V., (1860), p. 38, ou il est mentionnée."

"Dans le chapitre intitulé 'Determination de la latitude par les hauteurs reciproque' l'auteur montre en s'appuyant sur les 'Adversaria' pp. 6 and 7, que Romer fut l'inventeur de la methode actuellement appelée methode de Horrebow-Talcott. En 1894, Mr. P. Kempf était arrivé à un conclusion opposée (*Astr. Nachrichten*, No. 3241) étude non signalée par l'auteur."

The following account briefly outlines the statements which can be made for both astronomers.

In the "Adversaria," Rœmer announces: "the latitude from reciprocal meridian altitudes of Polaris to the north, and of the sun, or of a fixed star to the south; whatever may be the condition of the instrument, if the declinations are known, the altitude of the pole may be thence deduced." The above statement is followed by eight diagrams and six illustrative equations, in all of which Polaris is the only star considered for the object north of the zenith; furthermore, in the text, following the equations, the writer considers the use of a fixed star to the south, when the sun is "nimis depressus," but in no place do we find an alternate for Polaris mentioned. Rœmer also commends his instrument for portable use; and states that although the vertical circle may consist of an arc of 60°, only 5° or 6° need be accurately divided, which "is as great a difference of altitude as, it is expected, need be observed." He also says that the method necessitates "divisiones instrumenti rectè divisas" and that a certainty of two minutes may be expected from it.

We will add that this description was entered in a commonplace book (the "Adversaria") which, in 1739, was deposited in the library of the University of Copenhagen; and did not appear in a printed dress until 1910.

Horrebow, who had communicated his method to De Lisle in 1729, published it in 1732, in a volume entitled "Atrium Astronomiæ," which appeared seven years before Rœmer's

widow deposited the "Adversaria" with the University of Copenhagen; and, in 1741, two years after this deposit, the "Atrium Astronomiæ" was republished as part of Volume III., in a collected edition of Horrebow's works. In this last edition, chapter seven of the "Atrium" contains an account of three methods used in the determination of the latitude of the observatory at Copenhagen; and under the heading, "metodus tertia," he states: "I communicate and commend to public use a new method for determining latitude from reciprocal heights where, in an observatory by aid of the observatory instruments, or in any other way, the declinations of the fixed stars or of the sun in the solstices, the declinations are given." The advantages of the method for the use of travelers is strongly emphasized; and then he points out the great advantages it offers through the minimization of the effects of refraction which the principle of the method ensures. He describes the instrument that is to be used and one of its features is the system of wires, or threads in the diaphragm of the telescope,* whereby the differences of the meridional altitudes of the corresponding stars may be determined. He continues with the statement that this same instrument "for which they were indebted to Rœmer, of blessed memory" would be described later, in the "Basis Astronomiæ," as it had been used by Rœmer and himself for more than forty years for correcting the meridian positions of their instruments and "now the same instrument is suggested for the altitude from reciprocal observations with the highest hopes for its success." In the description in the "Atrium Astronomiæ" we find the broadest possible appreciation of the possibilities of the method; and from Horrebow's announcement of its scope, the means for its application, and his claims for the advantages it possesses, we realize that it was only the improvements in instrumental design and construction and in the values of the positions of the

* Robert Grant, "History of Physical Astronomy," p. 642, describes a diaphragm used by Rœmer and Horrebow, with which Horrebow claimed that the declinations of the heavenly bodies could be determined with an error not greater than 2″·5 or 3″; this diaphragm is shown in Horr. Op., Vol. 3, Plate IV., which illustrates the latitude instrument.

stars which subordinated his results to those obtained in present day practice.

Rœmer's description is a record of a special application of his instrument (in this case, one of several he describes) to which his attention in all probability was drawn by the fact that at his observatory the altitudes of the sun at the summer solstice, and of Polaris at upper culmination were nearly equal, differing only by about eleven minutes of arc. The restriction placed on the amplitude of the accurate graduation recommended for his instrument would make it unsuitable for the latitude determinations illustrated and described in his diagrams and text, except within a zone whose northern and southern limits would be each 3° distant from the parallel passing through Copenhagen. Moreover, he makes no mention of the practical elimination of the effects of refraction consequent upon the use of the method, an advantage of such impressive importance where stars low in altitude are employed for the altitude determination. These limitations on the generality and value of the method he had in view would easily account for his carelessness in making no other record of his discovery than the entry we find in his commonplace book. Moreover as, according to the "Basis Astronomiæ," Rœmer, by 1695, (when Horrebow was only 16 years of age), had introduced "the instrument for corresponding altitudes" for correcting the meridian positions of his large instruments; when we consider the superior refinement of the fixed instruments in his observatory for determining its latitude; in the absence of any mention of the method by Rœmer (except the one in the "Adversaria"), there is no violence in the assumption that this one special application had never been communicated to Horrebow.

For proof of the late date to which ignorance of any credit being due to Rœmer for the invention of the latitude method under consideration persisted, one need only point to Professor Kempf's article in *Astr. Nachrichten*, No. 3241, written as late as 1894, wherein the author, in his contention in behalf of Horrebow, states that Rœmer only used his instrument, the

"perpendiculum correspondentium" for the control of his meridian observations.

This furnishes fairly strong evidence of how much attention had been paid to and of the little estimation in which the manuscript of the "Adversaria" was held, despite the greatness of Rœmer's name.

That "it would be unjust to suspect Horrebow of having appropriated an original idea which Rœmer nowhere published" is conceded by M. Van Biesbrœck; and the terms in which he described Horrebow's single-minded devotion to the glory and renown of his venerated master could never be applicable to one who would rob the dead.

In the following quotation from Delambre's *Astr. Mod. Tom.* II., p. 633, we find a strong confirmation of the self abnegation and loyalty that M. Van Biesbrœck mentions:

> "À son tour il (Rœmer) eut un éléve dans l'astronome Horrebow qui parait lui avoir voué une espece de culte, et qui fut l'editeur du seul ouvrage qui nous reste de tous ceux que Rœmer avait composés."

To conclude: As Rœmer's extremely circumscribed account of the possibilities of the method of latitude determinations by means of differential measures of meridional altitudes was recorded with such little regard for its importance that it lay unknown until 1910, this late day publication of an imperfect statement of the possibilities of the method should not be allowed as competent reason for transferring, now, to Rœmer, the credit that has been accorded to Horrebow for his publication made 181 years ago; and which embraced, in a form that made it available for the use of the world, a description of his method that included the complete range of its possibilities and advantages; and moreover, when his claim that his method was a new one, is supported by his unimpeached character for devotion to and self effacement for, the glory of the man he would otherwise stand chargeable with attempting to despoil.

U. S. Coast and
Geodetic Survey.

MEETINGS OF THE SOCIETY

ANNUAL MEETING

The General Annual Meeting of the Royal Astronomical Society of Canada, was held in the Rooms, 198 College Street, Toronto, on January the 13th, 1914, Vice-President, Dr. A. D. Watson, in the chair.

The General Secretary reported having received and answered 132 communications officially during the past year.

Three General Council Meetings had been held during the year.

During 1913, the number of meetings held at the various Centres of the Society and the number of active members attached to each were reported as follows:—

Toronto, meetings held 17, active members 130.

Ottawa, meetings held 13, active members 90.

Peterborough, meetings held 12, active members 44.

Hamilton, meetings held 13, active members 34.

Guelph, meetings held 6 and a number of open air, active members 47.

Winnipeg, meetings held 10, active members 22.

Regina, meetings held 9, active members 32.

These, with 23 Honorary Members make a grand total of 422.

The reports from the Secretary of each Centre together with the lists of officers elected for 1914 are appended.

The Librarian reported the receipt of publications during the year, as follows:

Published in Canada and Empire -	227
Published in The United States - -	192
Published in other countries - -	171
Making a total of	590

10 books were donated during the year and 11 purchased by the Library Committee.

The number of books taken out by the members was 150.

The Treasurer's Report was received subject to approval of Council. Messrs. S. Beatty and Robt. Tyson were appointed Auditors.

Estimates for expenditure and Grants to Centres for 1914 on the same basis as for the last year were approved, payment to be made by the General Treasurer when instructed by the General Council.

The following were elected officers of the Society for 1914:

Honorary President—W. F. King, C.M.G., LL.D., Chief Astronomer, Ottawa.

President—J. S. Plaskett, B.A., D.Sc., Ottawa.

First Vice-President—A. D. Watson, M.D., Toronto.

Second Vice President—A. F. Miller, Toronto.

Secretary—J. R. Collins, Toronto.

Treasurer—Chas. P. Sparling, Toronto.

Recorder—Lachlin Gilchrist, M.A., Ph.D., Toronto.

Librarian—Dr. W. M. Wunder, Toronto.

Curator—R. S. Duncan, Toronto.

Council—H. B. Collier, Toronto; Rev. I. J. Kavanagh, S.J., D.Sc., Guelph; Rev. Dr. Marsh, F.R.A.S., Peterboro; Stuart Strathy, Toronto; Sir Joseph Pope, K.C.M.G., Ottawa; Otto Klotz, LL.D., F.R.A.S., Ottawa.

These, with the Past Presidents and the presiding officers of each Centre, constitute the General Council of the Society.

Dr. R. E. DeLury, Secretary of the Ottawa Centre, reported as follows:

Since the beginning of the year the Society has held thirteen regular meetings, eight in the Spring Series and five in the Fall Series. Of these, six were evening meetings as follows:—

SPRING TERM

"Present Progress in Astronomy," by R. M. Stewart.

"How Knowledge Grows," by Dr. J. C. Glashan.

"Some Glimpses of the Work along the 141st Meridian," by J. D. Craig.

"Astronomical Photography," by Frank Schlesinger.

FALL TERM

"The Work of the Dominion Observatory," by Dr. W. F. King.

"The Tides of Hudson Bay," by Dr. W. Bell Dawson.

Dr. Schlesinger's lecture was delivered in the Y.M.C.A. Hall, Dr. Dawson's in the Carnegie Library Hall and the others in the Dominion Observatory.

There were seven afternoon meetings as follows:—

SPRING TERM

"Notes from the Cleveland Meeting of the Astronomical and Astrophysical Society of America," by J. S. Plaskett and R. M. Stewart; and "Longitudes," by F. A. McDiarmid.

"The Grating Spectrograph," by J. S. Plaskett; and "A New Form of Clock Synchronization," by D. B. Nugent.

"Review of Current Progress in Astronomy," consisting of:—"New Theories of Evolution of the Solar System," by T. H. Parker; "Some Peculiarities of the Helium Stars," by W. E. Harper; and "Some Problems in Geophysics," by Dr. Otto Klotz.

"International Boundary Surveys from the St. Lawrence to the St. Croix," by Thomas Fawcett.

FALL TERM

"The Bonn Meeting of the Solar Union," by Dr. J. S. Plaskett.

"A New Method for Solar Observations," by Dr. R. E. DeLury; and "The Undagraph," by Dr. Otto Klotz.

"First Experiences with the Time Service," by D. Robertson; and "Level Errors," by F. A. McDiarmid.

It will thus be seen that thirteen topics were dealt with in the afternoon meetings — which were all held in the Dominion Observatory Lecture Room, — and following the custom, they were chiefly of a technical character. All the meetings were well attended and those attending were well repaid by the quality of the lectures.

During the year five members were elected and two resigned. The revised membership is now ninety. The Society has held a successful year and the prospects for the future are bright.

The following are the officers for the year 1914.

President—R. M. Stewart.

Vice-President—F. A. McDiarmid.

Secretary—R. E. DeLury.

Treasurer—D. B. Nugent.

Councillors—Thos. Fawcett, W. E. Harper, R. M. Motherwell.

These officers, together with Past Presidents, Dr. W. F. King, Dr. Otto Klotz, and Dr. J. S. Plaskett, constitute the committee.

T. H. Wingham, the Secretary of the Hamilton Centre, reports as follows :—

The Annual Meeting of the Hamilton Centre was held on December 12th, 1913.

The Secretary's and Treasurer's reports were received and adopted.

During the year six meetings were held with an average attendance of 54, as follows :—

Dec. 13, 1912—"Recent Convention of Astrophysical and Astronomical Society," Dr. Marsh.

Jan. 24, 1913—"How the Distances and Motions of the Stars are Determined," J. R. Collins.

Feb. 28—"Recent Visit to Greenwich," John A. Paterson.

Mar. 28—"Possibility of Life on Other Worlds," Harry Westoby.

April 26—"Celestial Photography," Professor Schlesinger.

May 30—"The Astronomical Yard-Stick," A. A. Hibner.

The election of officers resulted as follows:—

President—Wm Bruce.

1st Vice-President—W. A. Robinson.

2nd Vice-President—Rev. J. J. Morton.

3rd Vice-President—Edgar Scholes.

Secretary—T. H. Wingham.

Treasurer—Seneca Jones.

Executive—Miss I. M. Walker, J. F. Harper, Mrs. J. F. Harper, J. J. Evel, J. M. Williams.

Dr. D. B. Marsh, the Secretary of the Peterborough Centre, reported as follows:

It affords me pleasure to report the year 1913 to be the best we have had. All fees were paid promptly and on January 1st, 1914, no less than half of the members paid up till end of 1914. There is a hearty interest among the members and several of our young men are looking toward an Astronomical Course in the University of Toronto,—two intending to devote their lives to the study.

The Board of Education has generously supplied us with rooms, including light and heat, without charge.

The telescope so kindly loaned us by Mr. R. F. Stupart, Director of the Meteorological Service, is continually in use among the members; and the 3-inch telescope presented by Hon. J. R. Stratton has not been idle a week since it was donated two years ago.

The officers for 1914 are:—

President—T. A. S. Hay, C.E., Peterborough.

Vice President—T. C. Elliot, Peterborough.

Secretary-Treasurer—T. C. Elliot, Peterborough.

Lantern and Slides—H. O. Fisk, Peterborough.

Care of Telescopes and Librarian—John Halliday Crane.

Members of Council—The above officers with Duncan Walker, B.A.; S. J. Keyes, B.A.; W. A. Logan, C.E.; D. E. Eason, B.A.Sc.; Henry Carveth.

Professor R. R. Graham, Secretary of the Guelph Centre, reported as follows:—

I have pleasure in forwarding the Annual Report of the work done by the local centre of the Society during the year 1913. Six lectures were given during this time, all of which were much enjoyed, and they helped very much to sustain the interest in astronomy among our members.

The Society's six-inch telescope Mr. H. E. S. Asbury has taken charge of, and he has been most kind during the year in setting it up for the benefit of others. Not only has he issued a standing invitation open to all our own members to visit his home to see through it, but he has invited many others, who are not yet members of the Society, and in this way has done a lot of good, creating interest in astronomy, and spreading knowledge.

The Financial Report has already been submitted by Treasurer Leadley, and it shows how well this painstaking officer has looked after the local financing.

The election of officers was left to a local committee, and they report as follows:—

Honorary President—Colonel A. H. Macdonald, K.C.
Honorary Vice-President—Jas. Davison, B.A.
President—Henry Westoby.
1st Vice-President—Professor W. H. Day, B.A.
2nd Vice-President—Dr. H. G. Roberts.
Secretary—Professor R. R. Graham, B.A.
Treasurer—H. J. B. Leadley.
Recorder—J. T. Luton, M.A.
Council—J. McNiece, B.A.; H. E. S. Asbury, Colonel D. McCrea, F. A. Graesser, Sheriff A. S. Allan, W. Laidlaw, Mrs. J. J. Drew, Miss Mary Mills.

In conclusion, the members of the Society are all looking forward to a most interesting year, for which an excellent programme is planned, and doubtless the year will prove to be even more pleasurable than have the others.

Mr. C. E. Bastin, Secretary of the Winnipeg Centre, reported as follows:—

Our meetings have been held regularly during the year except during the summer months, when they were as usual discontinued except for occasional informal observation meetings.

Some of the meetings held during the early part of the year have been fully reported in the JOURNAL and all meetings were interesting and instructive and, perhaps, better attended than in the past.

Owing to the fluctuating nature of our population we lose a certain number of our members each year by removal to other cities, but these losses are replaced by new members so that our numbers remain about the same.

Officers for 1914:—

President—Professor L. A. H. Warren, M.A., Ph.D.

Vice-President—H. C. Howard.

Secretary-Treasurer—C. E. Bastin, B.A.

Council—Rev. Father Blain, S.J.; Professor N. B. MacLean, M.A.; Messrs. F. Powell, H. W. Malpass, J. H. Kolb.

J. R. C.

The Treasurer's Report is as follows :—

FINANCIAL STATEMENT

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

1913	RECEIPTS, 1913		
Jan. 1	Balance in Imperial Bank	$1917.41	
	Grant from Dominion Government	2000.00	
	Grant from Ontario Legislature	600.00	
	Grant from City of Toronto	100.00	
	Grant from University Library (for exchanges)	100.00	
	Fees to date, to December 31st	802.87	
	Interest on Deposits	54.35	
			$5574.63

1913	DISBURSEMENTS, 1913		
Dec. 31	Publication of JOURNAL and HANDBOOK	2005.66	
	Public Meetings	144.70	
	Books, Etc., for Library	197.15	
	Shelving for JOURNALS	15.25	
	Bank Charges on Cheques	1.85	
	Stationary and Postage Stamps	34.10	
	Salaries	310.00	
	Rent of Rooms	200.00	
	Storage of JOURNALS—Wicksey	2.00	
	Grant to Peterborough Centre	125.00	
	Grant to Ottawa Centre	85.00	
	Grant to Regina Centre	125.00	
	Cash Balance in Imperial Bank	2328.92	
			$5574.63

	CASH ASSETS, 1913		
	Balance in Savings Dept. Imp. Bank	144.70	
	Building Fund		
	C.P.L. & S. Co. Bond at 4½ percent.	872.40	
	C.P.L. & S. Co. Bond at 4½ percent.	500.00	
		$1372.40	
	Cash in Imperial Bank	2328.92	
			$3846.02

Respectfully submitted,

CHARLES P. SPARLING,
General Treasurer.

Audited and found correct,
(Signed) R. TYSON,
S. BEATTY.

Toronto, January, 1914.

OTTAWA CENTRE

FINANCIAL STATEMENT, 1913

RECEIPTS

Balance on hand, December 19, 1912 -	$ 40.62	
Annual Grant - - - - -	85.00	
Interest - - - - - -	2.03	
		$127.65

EXPENDITURES

Lectures - - - - -	$ 20.00	
Printing - - - - -	41.55	
Postage and Telegrams - - -	6.98	
Cartage - - - - -	.50	
Sundries - - - - -	.70	
	869.73	
Cash in Bank of Commerce, cheque,	$52.00	
Balance - - - - -	5.92	
	857.92	
		$127.65

Respectfully submitted,

D. B. NUGENT,
Local Treasurer.

Audited and certified correct,
(Signed) D. ROBERTSON,
J. B. CANNON.
Ottawa, December 18, 1913.

HAMILTON CENTRE

FINANCIAL STATEMENT, 1913

RECEIPTS

To Balance from 1912 - - -	$195.28

EXPENDITURES

Lecture expenses - - - -	$ 39.31	
Printing - - - - -	20.30	
Paid Fees (Press Rep.) - - -	18.00	
Balance in Bank - - - -	117.67	
		$195.28
December 12, 1913, To Balance on hand -		$117.67

Respectfully submitted,

SENECA JONES,
Local Treasurer.

Audited and compared vouchers
and found correct,
W. A. ROBINSON.
Hamilton, December 12, 1913.

PETERBOROUGH CENTRE

FINANCIAL STATEMENT, 1913

RECEIPTS

Grant from Toronto	$125.00	
Fees from members	86.00	
		$211.00

EXPENDITURES

Membership Fees to Toronto	$ 86.00	
Dr. Schlesinger's Lecture, to Mr. Spurling	20.00	
To Lecturers	50.00	
Lantern	10.00	
Slides	18.00	
Caretaker Instrument equipment Postage and Printing	20.25	
		$210.25
	$211.00	
	210.25	
By Cash to Credit		75

D. B. MARSH,
Local Secretary-Treasurer.

GUELPH CENTRE

FINANCIAL STATEMENT, 1913

RECEIPTS

Balance on hand, as per last statement	$ 98.42	
Membership Fees—Arrears for 1912	38.00	
Membership Fees for 1913	84.00	
Interest on account at Royal Bank	1.04	
Overdraft	3.00	
		$220.20

EXPENDITURES

Remittances to General Treasurer, Members Fees	$122.00	
Rent of Lecture Hall	15.00	
Caretaker	6.00	
Printing, Advertising and Postage	20.98	
Travelling Expenses of Lecturers	23.35	
Cartage on Lantern	2.50	
Lantern Slides	7.43	
Subscription towards Prof. Schlesinger's Tour	20.00	
		$220.20

H. F. B. LEADLAW,
Local Treasurer.

Audited and found correct.
(Signed) H. WESTOBY.
Guelph, December 27, 1913.

You will observe that no Grant was given to this Centre for the year just closing; and in consequence there is a small balance on the wrong side. It is to be hoped that a more generous consideration will be given for the year 1914.
H. F. B. L.

WINNIPEG CENTRE

FINANCIAL STATEMENT, 1913

RECEIPTS

1912 Balance on hand	$225.10	
1913 18 Subscriptions	36.00	
Interest	4.46	
		$265.56

EXPENDITURES

Caretaker (2 years)	$ 15.00	
Advertisement	5.04	
Printing and Post Cards	18.00	
Slides	4.36	
Remitted to Toronto	36.00	
Expenses—Dr. Gingrich's Lecture	35.50	
Postage	2.50	
	$116.34	
Balance on hand	149.22	
		$265.56

C. E. BASTIN,
Local Secretary-Treasurer.

Audited and found correct,
(Signed) H. W. MALPASS,
L. A. H. WARREN.
Winnipeg, November 26, 1913.

REGINA CENTRE

Report received too late for publication: will appear in next issue.

ORDINARY MEETINGS: AT TORONTO

November 4, 1913.—The meeting was held in the Society's Rooms, 198 College Street, at 8 p.m.

Mr. H. B. Collier gave the lecture of the evening on "Astrology in the Light of Astronomy." The lecturer gave a brief outline of a typical system of astrology. He discussed the historical development of astrology among the Egyptians, the Chaldeans, the Chinese, and the Greeks and pointed out the foundations of its growth. Illustrations of the use and significance of various astronomical signs were given and the part which these played in the lives of the people. The lecture was illustrated by numerous slides showing the development of astronomy from a superstitious belief, into an exact science. The lecture was discussed by Messrs. Collins, Gilchrist and others.

November 18.— The paper for the evening was by Dr. Albert D. Watson, on "Horrocks, the Pride and Boast of English Astronomy."

The reading of the paper was followed by an interesting discussion, participated in by several of the members.

December 2.— The President, Professor L. B. Stewart, gave an interesting account of the historical development of Geodetic work and the establishment of facilities for the work in connection with the University.

The meeting then adjourned so that the members who were present might pay a visit to the Geodetic Observatory to the east of the main building of the University.

December 16.— In the absence of the President, Dr. Wunder, occupied the chair.

The Secretary called attention to several articles of interest appearing in publications lately received by the Society.

Mr. J. L. Dudgeon, of Dovercourt Road, Toronto, was elected a member of the Society.

The paper for the evening was by Dr. C. A. Chant on "The Celestial Sphere and Its Uses."

The construction of the sphere was explained and a number of demonstrations were given illustrating how the times of sunrise and sunset may be determined and the position of right ascension and declination located for planets or stars at any time of year or from any part of the earth's surface. An interesting discussion followed and the general wish of the meeting was expressed that the lecturer would favor the members with a continuation of the discussion of such questions in the near future.

As the holiday season would intervene it was announced that the next meeting would be held on January 6th, 1914.

January 6, 1914.— In the absence of the President, Professor C. A. Chant occupied the chair.

Mr. J. R. Collins gave a brief synopsis of interesting papers

in recent numbers of the *Monthly Notices of the Royal Astronomical Society*, *Publications of the Astronomical Society of the Pacific* and *Popular Astronomy*.

Mr. I. R. Pounder, B.A., gave the lecture of the evening on "Relativity."

The lecturer described experiments on aberration and motion of the earth and the ether to show wherein the results conflicted. He presented the theory of relativity to reconcile those results. The postulates of relativity were given and some of the deductions made therefrom in the matter of units of length, time and mass and the question of simultaneity.

A number of members took part in the dicussion.

January 27.— The regular meeting of the Society was held in the Physics Building of the University on account of better facilities for demonstrating the lecture.

Mrs. Joseph Walker, 29 Walker Avenue, Toronto, was duly elected a member of the Society.

Professor C. A. Chant gave the lecture of the evening on "The motions of the Earth and the Moon." This lecture was the first of a course of three on "The Motions of the Heavenly Bodies."

The general impressions which one receives on first observing the sky were outlined, particularly with reference to the apparent motions of the moon, and stars, and the necessity for methods of marking the place of a body and measurement were pointed out.

The meaning of the elementary geometrical terms which are used in measurement was made clear and examples were presented to illustrate the use of the terms.

With the aid of models, the celestial hour circles, equator and the ecliptic, the apparent path of the sun in the heavens, were shown and the meaning of the terms Right Ascension and Declination was given and also the use of these in a star map to assist in locating the stars.

The meeting was largely attended.

February 3rd. — An extra meeting of the Society was held on February 3rd, in the Physics Building of the University.

Mr. J. A. Paterson occupied the chair.

Professor C. A. Chant gave the second of his course of lectures on "The Motions of the Planets."

A large number of the public were present and copies of the OBSERVER'S HANDBOOK were distributed to those interested.

L. G

AT OTTAWA

October 16th, 1913. — The first meeting of the Fall Term was held at 3 p.m. to-day in the Observatory Lecture Room, Mr. R. M. Stewart presiding. After the ordinary business of the meeting Dr. J. S. Plaskett was called upon to give his address on, "The Bonn Meeting of the Solar Union."

After briefly mentioning the purpose of the Solar Union and its previous four meetings, Dr. Plaskett turned to the meeting held last July and August in Bonn, Germany. The places of scientific interest in Bonn were mentioned including the University, the Observatory and the new Physical Science Buildings. The full programme of receptions and meetings was then described and the reports of the various committees outlined, and the plans for the future work and meetings of the Union were given.

Dr. Plaskett praised highly the hospitality of those in charge of the meetings.* After some words of appreciation by the President the meeting was adjourned.

October 30th. — The second meeting of the term was held this evening in the Observatory Lecture Room. In the absence of the President and the Vice-President, Dr. Plaskett kindly occupied the chair. Dr. Reynold K. Young, proposed at the last meeting, was duly elected a member of the Society.

Dr. W. F. King was then called to give his address on "The Work of the Dominion Observatory."

*A fuller account of the meeting is given in the last number of the JOURNAL. —ED.

After some introductory remarks the lecturer described the main instruments in use at the Observatory, outlining the results obtained by them. In referring to the fifteen-inch equatorial and its equipment and the work done with it, the lecturer outlined the plans for the new six-foot reflector. Then followed descriptions of the transit instruments and meridian circle, the time service, the cœlostat and spectrograph, and the seismographs, together with remarks on the work which has been done and is being carried on by these instruments.

In replying to the hearty vote of thanks accorded him Dr. King promised to address the Society on the other branches of the Observatory's work which could not be touched upon in the brief time of one lecture.

November 13th. — The third meeting of the Fall Term was held this afternoon at the Dominion Observatory, Mr. R. M. Stewart presiding.

Two subjects were presented at the meeting "A New Method for Solar Observations," by Dr. Ralph E. DeLury and "The Undagraph" by Dr. Otto Klotz. In the first the various causes which produce changes in wave-lengths or light emanating from any point in the sun were mentioned and it was shown how most of these were eliminated in the determination of the solar rotation velocity by taking the differences in the measures of the wave-lengths from opposite ends of a diameter. By photographing simultaneously a gas absorption spectrum for comparison, the effects of rotation, pressure and convection, and the component of the earth's orbital motion could be measured. By many measurements distributed over a year the value of the sun's distance could be obtained, while very many of these easily made observations by many observers might yield an accurate determination of this distance. A lantern slide showed several strips of spectra: two rotation strips for each edge, one strip from the centre of the sun and outside these two strips of iodine comparison spectrum taken simultaneously by means of a special arrangement of notched prisms and an iodine absorption tube.

After some discussion on the first paper, Dr. Klotz proceeded with the description of the Undagraph, designed and named by himself. The Undagraph was set up at Chebucto Head outside of Halifax Harbor for the purpose of correlating the period and amplitude of the ocean waves with that of the microseisms recorded on the seismographs, it having been previously noticed that the microseisms were greatest at the times of the greatest storms on the Atlantic Coast. Lantern slides were shown of the location of the instrument and of the instrument itself with the pipe connection to the water. The waves produce compression of air in the pipe and this is communicated to a diaphragm which moves the recording point. Results so far obtained seem to justify the conclusion that the pounding of the waves on the sea coast produces the microseisms. After some discussion the meeting was adjourned.

November 27th. — The fourth of the term was held this evening in the Carnegie Library Lecture Hall, Mr. R. M. Stewart presiding.

Professor Bernard Gavin, Ottawa University, proposed at the last meeting, was duly elected a member of the Society.

Dr. Bell Dawson, was then called on to give his address on "The Tides of Hudson Bay."

Dr. Dawson pointed out the necessity of a knowledge of the tides for purpose of navigation; and since the Hudson Bay region is rapidly opening up, it is imperative that the tides there be accurately tabulated for different ports and possible harbors. The tides were observed (in 1884–5–6) under great difficulties by Ashe, Stupart, Tyrrell, McKenzie and others, at various points where the water is shallow in Hudson Bay, and a knowledge of the rise is very important; and in Hudson Strait, where the tides have a great range and the induced currents are strong. One way to prepare tables for the necessary points in Hudson Bay would be to send out expensive expeditions for the purpose; but Dr. Dawson adopted a simpler and inexpensive method. The types and ranges of the tides at the points in question are

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known,—chiefly from the early observations,—and consequently by selecting a port for which the type is similar, and, for which the tide tables are accurately worked out, it is possible to compute tables for the desired port. In this way, the tide-tables of Bremerhafen in the North Sea were used in computing the tide-tables for Nelson, both of the estuary type. Dr. Dawson having predicted that the two parts would have similar types from the fact that the North Sea and Hudson Bay are somewhat similar off-shoots from the North Atlantic Ocean. In a similar manner the tide-tables of Harwich served in the computations for Churchill; and the tides of St. John, N. B., have been harmonized with these of Hudson Strait, observed (in 1884-5-6).

During the course of the lecture Dr. Dawson described the types of tide, — the Spring and Neap tides,—those due to the changing declination of the sun and of the moon, and those due to the changing distance of the moon. He illustrated by charts the observations of 1884-5-6 for Nelson, Churchill, Moose Factory, Hudson Strait and James Bay. He compared the tidal curve with a sound curve such as produced on the phonograph record by musical notes of different kinds blended together saying that, "In the great orchestra of the Tides the sun and moon take all the parts."

After some discussion a hearty vote of thanks was tendered the lecturer. The meeting was then adjourned.

December 11th. — The fifth meeting of Fall Term, was held to-day at the Dominion Observatory, Mr. R. M. Stewart presiding.

Mr. Thomas Donoher proposed at the last meeting was duly elected a member of the Society.

Two papers were presented :—"First Experiences with the Time Service," by Mr. D. Robertson; and "Level Errors," by Mr. F. A. McDiarmid, M.A.

Mr. Robertson explained how the time is transmitted from the Observatory to the time-ball on Parliament Hill, and to the electric dials in the various Government Buildings. Running

from the Observatory to the city there are four insulated wires, one pair used by the time-ball, while the other pair divides into several branches carrying synchronization current for the master clocks in seven Government Buildings equipped with regulators and electric dials. The battery power for the uptown system is obtained from nine storage cells situated in the regulating room of each building, giving a potential of about eighteen volts. The minute dials are divided into circuits of ten which branch off wherever convenient from a pair of mains running to the switch-board. One of the clocks is placed in the regulating room to check the coincidence of the system with the master clock. Each dial has a resistance of 10 ohms and each circuit a resistance of 100 ohms.

Mr. McDiarmid gave a short description of the Talcot method of latitude determination. An examination of the determinations of latitude at Stony Plains, Bancroft, Edmonton, Morristown, Bella Coola, Bamfield, Sixth Cabin, Murray Hill and Galiano Island, showed that the larger errors in latitude determination are probably due to the faulty tabulated values of declination of the stars employed, which are based on early determinations and likely therefore to be in error due to faulty determinations of proper motion. The individual observations of the different pairs were also examined and probable error of a single determination independent of the errors of declination was found. This probable error included the probable errors both of micrometer and level. A large number of pairs having been observed where a star on one side of the zenith was paired with two or more stars on the opposite side, an opportunity was given of determining the probable errors of the micrometer readings. The probable error of the level was then found by taking the difference between the probable error of a single determination and the probable error of micrometer. The probable errors of a single determination, of micrometer settings, and of level readings, are :—

Morristown, ± 0″·45, ± 0″·20, ± 0″·40 ;
Bamfield, ± 0″·40, ± 0″·26, ± 0″·30 ;

Bella Coola,	± 0″·39,	± 0″·25,	± 0″·30 ;
Murray Hill,	± 0″·38,	± 0″·23,	± 0″·30 ;
Edmonton,	± 0″·33,	± 0″·19,	± 0″·27 ;
Sixth Cabin,	± 0″·33,	± 0″·19,	± 0″·27.

These results show that the errors due to level are slightly larger than the errors due to micrometer. Reference was also made to a new Hyde Instrument used part of the past year for the first time. It is a small instrument of the small telescope type. It weighs but 150 pounds in its travelling boxes as against 700 pounds of the Cooke instrument. The results obtained by it were just as good as any ever obtained with the larger instrument. On account of its lighter weight, it is very easily carried either in canoe or on pack-horses.

After some discussion the meeting was adjourned.

December 18th.— The Annual Meeting of the Ottawa Centre was held this evening, at 8 p.m., at the Dominion Observatory, Mr. R. M. Stewart presiding.

The minutes of the last Annual Meeting were read and approved.

The Secretary read a short report showing the satisfactory condition of the affairs of the Society with regard to the number and quality of the papers presented and the steady increase in its membership. It was moved by the Secretary that this report be adopted ; seconded by Mr. J. J. McArthur and carried. The Treasurer read his report showing the satisfactory condition of the finances of the Ottawa Centre. It was moved by the Treasurer that this report be adopted ; seconded by Mr. Thos. Fawcett and carried.

Messrs. W. C. Way, W. A. Dier and D. Robertson proposed at the last meeting were duly elected members of the Society.

The officers for 1914 appear in the Annual Report on another page.

After some discussion and some suggestions for the "At Home" proposed for the coming term, the meeting adjourned.

January 15th, 1914 —The first lecture of the Spring Term, 1914, was held in the Dominion Observatory this evening, Mr. R. M. Stewart presiding.

Mr. H. S. Southam, of "The Citizen," proposed at the last meeting, was duly elected a member of the Society.

The following proposals for membership were made:—Mr. George L. Rainboth, Trafalgar Building, by Thos. Fawcett and Noel J. Ogilvie; Mr. D. H. McDougall, Sydney N. S., by M. J. Butler and W. E. Harper; Mr. Albert George Ewens, 92 Gilmour Street, Ottawa, by R. E. DeLury and R. M. Motherwell.

Dr. W. F. King was then called upon to give his address on "The Work of the Dominion Observatory." In this lecture—a continuation of his address of last term—Dr. King dealt with the following branches of the Observatory's work:

(1) THE PHOTOGRAPHIC BRANCH in which copying, enlarging, development of survey plates and seismograms, etc., are done,—particular descriptions being given by the photographic method in surveying—devised by Dr. Deville and used extensively in the Alaskan Survey work and recently adopted by the United States Surveys;

(2) THE MACHINE SHOP and its uses and importance in all the lines of work where special apparatus and repairs are required;

(3) THE LIBRARY with its 5000 volumes, journals and pamphlets covering the fields of astronomy, physics, chemistry, geophysics;

(4) THE COMPUTING AND MEASURING INSTRUMENTS were then described. Lantern slides were used in illustration.

The importance of good instruments and time-saving machines were emphasized, and the necessity and value of meetings held at the Observatory were pointed out.

A hearty vote of thanks was given to the lecturer, after which the meeting adjourned.

January 29th—The second meeting of the Spring Term was the "At Home" held this evening 8-11.

The Director, Dr. W. F. King and Mrs. King, and the President, Mr. R. M. Stewart and Mrs. Stewart received the guests who numbered about 160.

The various rooms of the Observatory were thrown open with the exhibits and demonstations including: The Library and Reading Room; Earthquake Records, Seismographs, Gravity Pendulum for measuring the figure of the earth; Time Service, Clocks, Chronographs, Wireless Signals (sending and receiving), Meridian Circle, and Transit Instruments; Terrestrial Magnetic Instruments and Earth Inductor; Boundary Survey Instruments, Maps, Photographs, Spectroscope, Spectrum of Carbon Arc, Stellar Radial Velocity Measuring Engines, Photographs; Stellar Photometer, Spectro-Comparator; Harmonic Analyser, Computing Machines; Geodetic Survey Instruments, Precise Levelling, Model Observatory Tower and Base Line; Solar Laboratory, Direct Vision Spectroscope, Solar Photographs and Measuring Engine, Littrow Spectrograph, Cœlostat; Equatorial Telescope and Attachments. During the evening moving pictures of Yukon Surveys were shown three times.

February 12th.—The third meeting of the Spring Term was held in the Dominion Observatory to-day, 3 p.m., Mr. R. M. Stewart presiding.

Messrs. George L. Rainboth, D. H. McDougall and A. G. Ewens, proposed at the last meeting were duly elected members of the Society.

Dr. Klotz was then called upon to give his address on "The Atlanta Meeting of the A. A. A. S."

This association met in Atlanta, Georgia, December 29th to January 3rd last, nearly all the scientific Societies of America being represented. Dr. Klotz then mentioned a number of interesting papers given before the Astronomical Section giving particular reference to: the address of the President, Professor E. C. Pickering, on "The Study of the Stars." The paper by

Father Rigge; on "The Arlington Wireless Signals;" the paper on "Isostasy," by Professor Bowie; and the paper on "Factors Contributing to Climatic Conditions," by Professor Humphreys. In speaking of Father Rigge's paper, Dr. Klotz stated that the time of transmission of the wireless signals from the Eiffel Tower to Arlington a distance of 3835 miles was found to be 0.063 second, *i. e.*, at the rate of 122,000 miles per second as compared with 186,000 miles per second for the velocity of light and about 12,000 miles for the velocity of electricity along a wire. The comparison for longitude between the points gave a difference of 279 feet (0·025 sec.) greater than expected. This suggested to Dr. Klotz an additional confirmation of Wegener's theory that the continents are separating.

Interwoven with the account of the meetings Dr. Klotz gave some general remarks on the country and the people, and spoke of the work of several scientific institutions which he visited and in particular of the apparatus devised by Professor Fisher at Washington for detecting deformations of the earth.

A hearty vote of thanks was tendered the lecturer after which the meeting adjourned.

February 26th.—The fourth meeting of the Spring Term was held in the Dominion Observatory this evening at 8 o'clock, Mr. R. M. Stewart presiding.

Mr. A. H. Swinburn, proposed at the last meeting, was duly elected a member of the Society.

Dr. W. F. King was then called upon to give his third and concluding lecture of his series on "The Work of the Dominion Observatory."

Dr. King dealt with the Boundary and Geodetic Surveys. He spoke first of the surveys of the boundary between Canada and the United States from the Atlantic to the Pacific. He quoted the various treaties which fixed these boundaries and mentioned the difficulties and differences in their interpretation. The treaty of 1783 described the boundary line from the St. Croix to the Mississippi. Great difficulties arose and the King

of the Netherlands was chosen as arbitrator. His decision satisfied neither Great Britain nor the United States. Later the Ashburton-Webster Treaty followed, by which Canada received 700 square miles more than the decision of the King of the Netherlands would have given her. In 1913 the boundary bteween the Panhandle of Alaska and British Columbia was arbitrated. In 1906 the 141st meridian was fixed between Alaska and the Yukon and the subsequent surveys located it more closely, fixing points along it. The surveys are now nearly completed and the boundaries definitely located in accordance with the treaties mentioned above.

Dr. King then outlined the purposes, methods and future work of the Geodetic Survey. He showed the difficulties in selecting points for the observing towers, and how the observations are made from them. He showed the extent to which precise levelling had been carried out throughout the Dominion.

After a hearty vote of thanks had been tendered the lecturer the meeting adjourned.

R. E. DEL.

At Hamilton

December 12th. — The chair having been taken by Mr. W. A. Robinson, he called upon Mr. Bruce to give the lecture for the evening entitled "Some Wonders of the Heavens and Where to Find Them with a Telescope."

A very instructive and interesting lecture was then given. The following constellation were dealt with :— Ursa Minor, Draco, Ursa Major, Camelopardalis, Cassiopeia, Cepheus, Cygnus, Lyra, Hercules, Corona, Bootes, Canes Venatici, Coma Berenices, Leo, Cancer, Auriga.

The positions, chief stars, nebulæ, variables, etc., of each constellation were pointed out together with many other interesting details.

At the close a hearty vote of thanks was tendered the lecturer, who promised at some future time to complete the list of constellations.

January 23rd. 1914. — The meeting was held in the rooms of the Centre in the old Public Library Building.

The President, Wm. Bruce, gave an account of some observations on meteors.

Charles Richards, 39 St. Mathews Ave., was elected a member of the Society.

Professor C. A. Chant, was then called upon and gave a lecture on the "Astronomical Phenomena for 1914," with especial reference to the Society's HANDBOOK.

The HANDBOOK was much valued by the members before, but after the lecture it was much more so.

At the close of the lecture a hearty vote of thanks was tendered the lecturer.

February 13th. — The meeting, which was fairly well attended, was presided over by the President of the Centre, Wm. Bruce.

Duncan Chisholm, 195 Emerald St. N., was elected a member of the Society.

Dr. A. A. Hibner gave a lecture on "Cosmogony, or the Creation of the Heavens."

By the aid of a number of fine slides the lecturer pointed out a number of the more interesting celestial objects, referring to the distances and rates of radial velocity observed in the chief stars.

The lecturer then took up the subject of cosmogony, giving the three views that are held by astronomers concerning the origin of the world. The first represented the world as eternal, in form as well as substance. The second, that the world had a beginning and should have an end. This was the Mosiac cosmogony. The third, that the matter but not the form of the world was eternal.

The next topic discussed was how the sun obtained and maintained its heat. Professor Langley said if we took all the coal from all the coal fields of the whole world and cast it into the sun to be burnt it would not produce as much heat as the

sun used in the tenth part of a second. The sun maintained its heat by contraction of about a mile in every 11 years. The diameter of the sun was five miles less when the late Queen Victoria ended her rule than it was when she mounted the throne. It was 170 miles smaller than when it shone on the sea of Galilee when the Son of Man walked upon that sea. This made the contraction about 16 inches every 24 hours. In a few millions of years the photosphere of the sun would become solified and its spectrum changed. Within the next 10,000 years we should enjoy perpetual summer in the arctic regions and a frigid climate in the torrid zone.

The speaker next spoke of the nebulæ, comets, temporary stars and other worlds in the act of creation, stating that the stellar universe was not a "perfect system" but a "survival of the fittest."

He concluded by stating that we travelled through space at the rate of 375 million miles every year. What constellations were present a million years ago? A few million years hence people would not see the stately form of Orion, not the Big Dipper holding water, nor will Cassiopeia form a resting place for Andromeda. Likewise, Sirius and Vega would no longer be in view. Polaris would have vacated its position as pole star to guide the mariners upon the sea, and a new "heaven," would be their heritage.

With the above Professor Hibner concluded a very interesting lecture.

T. H. W.

At Peterborough

October 28th 1913.—The opening meeting of the Fall Session of the Peterborough Centre was held in the Physical Laboratory of the Collegiate Institute, this evening.

The President, Mr. T. A. S. Hay, was in the chair, and after the usual routine business Rev. T. W. Goodwill, B.A. of Keene; and Rev. S. B. Rohold, F.R.G.S., 165 Elizabeth St., Toronto, were received as members.

Mr. Hal. Crane gave a very interesting account of his observations of Jupiter with the Stratton Telescope, after which Dr. Marsh addressed the meeting on "Astronomy for Beginners."

November 25th. — The regular meeting was held in the Collegiate Institute. The President, Mr. T. A. S. Hay, C.E., in the chair. Rev. Dr. Marsh gave a lecture on "The Planets."

The meeting was well attended.

December 10th.—The Annual Meeting was held in the Collegiate Institute. The President, Mr. T. A. S. Hay, C.E., in the chair.

The financial report showed a balance of 75c. in the treasury, 44 members in all and a much increased interest taken in the work.

After the business was over, Rev. Dr. Marsh, the retiring Secretary, was presented with a handsome travelling club bag and an address.

A lecture here followed by Dr. Marsh on "The Physical Constitution of the Sun," which was appreciated by the very large audience. After adjournment, a luncheon was given in honor to Dr. Marsh, who is leaving Peterborough to reside in Holstein, Ontario.

D. B. M.

At Winnipeg

The Programme for the First Term.

October 22, 1913 — Some Old Problems in Astronomy." H. W. Malpass.

November 12 — "The Moon." H. C. Howard.

November 26 — Annual Meeting. "Multiple Stars." Professor L. A. H. Warren, M.A., Ph.D.

December 10 — "Recent Development in Solar Research." Professor N. B. McLean.

C. E. B.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

December, 1913

Temperature.—The month was considerably warmer than normal in nearly all parts of the Dominion. The positive departure reached a maximum of 5° in the Upper Fraser Valley, while it was only at a very few points in South Vancouver Island, the East Kootenay, and on the North Columbia River that there was a slight negative departure. Mean temperatures were from 3° to 8° above normal in Alberta, from 6° to 12° above in Saskatchewan, and from 7° to 13° above in Manitoba. In Ontario, positive departures varied from 4° to 11°, except locally in the interior of the Southern Peninsula, where they fell as low as 1°. Eastward from Ontario, likewise, the month was everywhere warmer than usual, the deviation from normal temperature varying from 4° to 9° in Quebec, from 4° to 8° in New Brunswick and from 1° to 3° in Nova Scotia, while all stations in Prince Edward Island reported about 3° above normal.

Precipitation.—Precipitation during the month fell short of the average in all parts of the Dominion, the deficiency being considerable in most parts of the country. In British Columbia the precipitation varied from 40 per cent. of the normal on the Lower Fraser, and in the Thompson Valley, to 75 per cent. on South Vancouver Island. In the Prairie Provinces the amount was in nearly all districts only from 5 per cent. to 20 per cent.

of the normal while from some localities none is reported. In Ontario the amount reported varied from 10 per cent. of the average in the Thunder Bay region, to 65 per cent. in the Upper St. Lawrence and Ottawa Valleys. Throughout the Southern Peninsula of the Province, however, the percentage did not exceed 40. In the provinces to the eastward of Ontario the fall for the month was greater, the amount recorded varying from 65 per cent. of the normal, in parts of Quebec, to the normal amount, or slightly over, locally in Nova Scotia. There was considerably less than the usual amount of snow on the ground in the various sections of the country at the close of the month.

January, 1914

Temperature. — In British Columbia, temperatures for the month varied from somewhat below normal in parts of the northern mainland, to 3° and more above normal in the southern districts. In the Prairie Provinces, mean temperature varied from 3° to 8° above average everywhere except in Northern Alberta, where it was slightly below. In Ontario the month was on the whole a mild one in the northern and western portions of the Province, while, in marked contrast to this, in the Ottawa Valley and eastern districts it was colder than usual. The mean temperature was from 2° to 5° above average in the former, and about 2° below average in the latter districts. In Quebec, mean temperatures were slightly below average over the greater part of the province; and in the Maritime Provinces there was likewise a negative departure, amounting in these provinces to from 1° to 3°.

Precipitation. — Precipitation for the month was much above normal in nearly all parts of British Columbia, the excess reaching as high as 90 per cent. on South Vancouver Island. In the Western Provinces, the precipitation was in most districts more than the average, twice the normal fall occurring in parts of Western Manitoba and Southwestern Saskatchewan, and in Southern Alberta. A slight deficiency, however, was reported

from parts of Eastern Manitoba and Northwestern Saskatchewan. In Ontario, except in the vicinity of the Georgian Bay, the fall was more than average, and fell largely as snow, which occurred at frequent intervals throughout the month. The precipitation was a little more than average in Western Quebec, and considerably less than average in the eastern portion of the Province, and also in the Maritime Provinces. At the close of the month, snow covered the ground in all parts of the Dominion except locally in the Southern Peninsula of Ontario and in parts of Nova Scotia.

Temperatures for December, 1913, and January, 1914

Station	December Highest	December Lowest	January Highest	January Lowest
Yukon				
Dawson	30	38		
British Columbia				
Atlin	38	0		
Agassiz	50	29	40	12
Barkerville	44	- 5	36	25
Kamloops	46	14	50	1
New Westminster	44	33	52	22
Prince Rupert	63	28	50	8
Vancouver	48	27	56	26
Victoria	50	30	52	28
Western Provinces				
Battleford	46	10	40	35
Broadview				
Calgary	54	2	50	24
Carman				
Edmonton	60	12	42	20
Medicine Hat	55	6	50	20
Minnedosa	40	23	42	42
Moose Jaw	54	7	48	33
Oakbank	48	16	33	30
Portage la Prairie	48	15	38	20
Prince Albert	44	25	36	35
Qu'Appelle	46	9	50	30
Regina	48	15		
Swift Current	58	4	56	34
Winnipeg	48	14	34	26
Ontario				
Agincourt	52	2	48	25
Aurora	49	6	44	30
Bancroft	45	10	50	35
Barrie	48	1	45	30
Beatrice	45	8	46	33
Birnam	51	9	52	11
Bloomfield	50	2	44	29
Brantford	53	2	55	22
Bruce Mines	52	3	43	35
Chatham	58	16		
Clinton	53	3	52	10
Cottam	56	10	60	5
Gravenhurst	47	7	47	35
Guelph	48	2	51	23
Haliburton	45	10	49	38
Hamilton	52	6		
Huntsville	55	8	49	36
Kenora	41	17	34	30
Kinmount	46	16	46	30
Kingston	49	0	45	28
Lakefield	59	2	54	34
London	50	2	54	13
Lucknow	49	5	50	14
Madoc	49	2	45	31
Midland	55	4	50	30
North Gower		8	38	32
Otonabee				
Ottawa	41	4	42	30
Owen Sound				
Paris	50	5	51	20
Parry Sound	46	4	52	10
Peterboro'	49	6	48	32
Port Arthur	50	9	30	22
Port Burwell	49	0	45	16
Port Dover	53	5	52	25
Port Stanley	51	5	47	11
Rouville	46	4	46	38
Sarnia				
Southampton	48	2	52	10
Stonecliffe	42	8	46	32
Stony Creek	52	3	57	15
Stratford	42	3		
Toronto	54	6	50	22
Uxbridge	50	10	49	30
Wallaceburg	54	14	65	4
Welland	51	4	56	15
White River	43	34	37	38
Quebec				
Brome	42	16	43	32
Father Point	36	0	35	20
Montreal	42	2	40	28
Quebec	38	1	43	24
Sherbrooke				
Maritime Provinces				
Charlottetown	50	10	42	6
Chatham	41	3	43	21
Dalhousie	55	4	43	13
Fredericton	47	12	45	24
Halifax	54	14	52	8
Moncton	53	13	47	15
St. John	50	8	47	10
St. Stephen	50	12	47	28
Sussex	52	7	46	27
Sydney	56	12	50	0
Yarmouth	53	17	44	1

from parts of Eastern Manitoba and Northwestern Saskatchewan. In Ontario, except in the vicinity of the Georgian Bay, the fall was more than average, and fell largely as snow, which occurred at frequent intervals throughout the month. The precipitation was a little more than average in Western Quebec, and considerably less than average in the eastern portion of the Province, and also in the Maritime Provinces. At the close of the month, snow covered the ground in all parts of the Dominion except locally in the Southern Peninsula of Ontario and in parts of Nova Scotia.

Temperatures for December, 1913, and January, 1914

Station	December		January	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	30	38		
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Agassiz	50	29	49	12
Barkerville	44	- 5	36	25
Kamloops	46	14	50	1
New Westminster	44	33	52	22
Prince Rupert	63	28	50	8
Vancouver	48	27	56	26
Victoria	50	30	52	28
Western Provinces				
Battleford	46	-10	40	35
Broadview				
Calgary	54	2	56	-24
Carman				
Edmonton	60	-12	42	-29
Medicine Hat	55	6	56	29
Minnedosa	40	23	42	-42
Moose Jaw	54	7	48	33
Oakbank	48	10	33	30
Portage la Prairie	48	-15	38	-26
Prince Albert	44	-25	36	35
Qu'Appelle	46	- 9	50	-30
Regina	48	15		
Swift Current	58	4	56	34
Winnipeg	48	14	34	26
Ontario				
Agincourt	52	2	48	-25
Aurora	49	- 6	44	30
Bancroft	45	-19	50	-35
Barrie	48	1	45	30
Beatrice	45	- 8	46	-33
Birnam	51	9	52	-11
Bloomfield	50	2	44	29
Brantford	53	2	55	22
Bruce Mines	52	- 3	43	35
Chatham	58	16		
Clinton	53	3	52	-10
Cottam	56	-10	60	- 5
Gravenhurst	47	7	47	-35
Guelph	48	- 2	51	-23
Haliburton	45	10	49	-38
Hamilton	52	6		
Huntsville	55	- 8	49	36
Kenora	41	17	34	-30
Kinmount	46	16	46	30
Kingston	49	0	45	28
Lakefield	59	- 2	54	-34
London	50	2	54	13
Lucknow	49	- 5	50	-14
Madoc	49	2	45	-31
Midland	55	4	50	30
North Gower		8	38	32
Otonabee				
Ottawa	41	- 4	42	-30
Owen Sound				
Paris	50	- 5	51	-20
Parry Sound	46	- 4	52	-10
Peterboro'	49	6	48	-32
Port Arthur	50	9	30	22
Port Burwell	49	0	45	16
Port Dover	53	5	52	-25
Port Stanley	51	5	47	-11
Ronville	46	- 4	46	-38
Sarnia				
Southampton	48	2	52	10
Stonecliffe	42	- 8	46	-32
Stony Creek	52	3	57	15
Stratford	42	3		
Toronto	54	6	50	22
Uxbridge	50	10	49	30
Wallaceburg	54	14	65	4
Welland	51	4	56	-15
White River	43	-34	37	-38
Quebec				
Brome	42	16	43	32
Father Point	36	0	38	20
Montreal	42	2	40	28
Quebec	38	1	43	24
Sherbrooke				
Maritime Provinces				
Charlottetown	50	10	42	6
Chatham	41	3	43	-21
Dalhousie	55	4	43	-13
Fredericton	47	-12	45	-24
Halifax	54	14	52	- 8
Moncton	53	13	47	15
St. John	50	8	47	-10
St. Stephen	50	12	47	-28
Sussex	52	7	46	-27
Sydney	56	12	50	0
Yarmouth	53	17	44	1

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.
Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1913-14	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm	h m	
1308	Dec. 6	0 30·2			0 35·8	0·05	0 5·6	
1309	" 6	15 9·5?	15 17·2	15 19·6	15 52·4	0·2	0 42·9	
1310	" 21	16 12·7?	16 41·5	16 45·5	A.C.	1·0		
1311	" 25	7 1·0?	Air	Currents				
	1914							
1312	Jan. 12	10 14·3	10 27·8		10 48·2	0·2	0 33·9	
1313	" 15	20 7·1	20 31·3		20 49·6	0·1	0 42·5	A. C. going on.
1314	" 20	12 21·4	12 38·0		12 18·5?	0·2	0 57·1	Marked thickenings.
1315	" 30	No Pts.	3 58·3	4 1·0 4 48·0	6 32·0	0·8) 1·3)	2 33·7	
1316	" 30	7 58·3?			8 34·5	0·05	0 36·2	

Period 17·7 seconds. 1 mm. = 0″·59.

VICTORIA, B. C.

F. N. Denison, Superintendent.

No.	Date 1913-14	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1313	Dec. 6	0 24·1			0 26·3	0·05	0 2·1	
1314	" 6	14 56·5?	14 59·5		15 7·5	0·1	0 11·0	
1315	" 21	16 21·9	16 28·8	16 32·9	17 24·0	0·7	1 02·1	
1316	" 25		7 26·4	7 27·4	7 31·4	0·3	0 5·0	P.Ts. possibly not recorded.
	1914							
1317	Jan. 7	19 55·7			20 30·2	0·1	0 34·5	Grad. thickenings.
1318	" 7	20 6·8			20 12·1	0·2	0 5·5	Grad. thickenings.
1319	" 12	10 13·1			10 38·6	0·05	0 25·5	
	" 15	Attending to instrument record of				quake	lost	
1320	" 20	12 15·2	12 18·8	12 19·0	12 59·1	0·3	0 43·9	Well defined.
1321	" 26	17 20·0		17 22·5	17 33·9	0·2	0 13·9	Grad. beginning.
1322	" 26	23 4·1	23 15·1		23 25·0	0·2	0 20·9	Grad. begin'ng and ending.
1323	" 30	3 41·6?	3 59·9	4 30·0) 5 4·7)	6 39·7	1·0) 1·3)	2 58·1	A.C. at beginning. [West'ly gale.
1324	" 30	8 2·9	8 28·0		8 59·2	0·1	0 56·3	Thickenings.

Period 18 seconds. 1 mm. = 0″·54

J. Y.

EARTHQUAKE OF FEBRUARY 10TH

There were two seismic disturbances recorded on February 10th. The first at $21^h\ 40^m{\cdot}9$, the centre of the earthquake being in the Panama zone. The second was a local one and was recorded at $13^h\ 32^m{\cdot}5$ when the boom showed a sudden vibration and then with the exception of a slight tremor at $13^h\ 45^m{\cdot}4$ came gradually to rest at $13^h\ 45^m{\cdot}9$. This earthquake was felt throughout Quebec, Ontario, as far south as Washington and the New England and New York States. In Toronto pictures swayed and tall buildings vibrated slightly. The earthquake appeared to be more severe in the St. Lawrence Valley. The last marked local earthquake which we recorded was on May 27th, 1912. This was also felt in Toronto.

While observing with the Declinometer at Agincourt on February 10th, Mr. Jackson noted at $13^h\ 32^m$ a vibration imparted to the mirror attached to the magnet, causing the reflected ray of light to move in the vertical plane and lasting for about 4 or 5 minutes. As the mirror is hanging almost in the plane of the meridian, this would indicate a wave in the earth's crust in an E. W. or W. E. direction. No indication of this movement would be recorded on the cylinder as the movement of the ray of light would be in the line of motion of the cylinder.

RECORDS OF TWO EARTHQUAKES AS GIVEN BY THE MILNE SEISMOGRAPH AT THE METEOROLOGICAL OBSERVATORY, TORONTO

MAGNETIC OBSERVATIONS

During the months of December and January the magnetic forces as depicted by the photographic curves obtained at Agincourt were for the most part normal. Small disturbances were recorded in December on the 4th, 5th, 7th, 25th, 26th and 27th, and in January on the 4th, 5th, 6th, 12th, 13th, 15th, 16th, 17th, 21st and 22nd. The largest of these was on the last two mentioned days and in this disturbance the amplitude in Declination was only 33'·9 and in Horizontal Force 59 γ.

Declination

Month	Mean of Month	Max.	Date	Min.	Date	Monthly Range	Amplitudes—Mean Daily	
							From hourly readings	From Means of Extremes
1913	° ′	° ′		° ′		° ′	′	′
Dec.	6 20·7	6 32·3	26	6 1·3	25	0 31·0	4·5	7·6
1914								
Jan.	6 21·2	6 34·4	22	6 0·5	21	0 33·9	4·7	8·2

Horizontal Force—C.G.S. Units

1913								
Dec.	0·16104	0·16125	18	0·16061	25	0·00064	0·00017	0·00028
1914								
Jan.	0·16107	0·16133	4	0·16065	21	0·00068	0·00016	0·00030

Inclination

Month	Mean Earth Inductor
	° ′
1913	
December	74 41·0
1914	
January	74 41·0

NEW OBSERVATORY AT VICTORIA, B.C.

During the past year a small Meteorological and Seismological Observatory has been erected at Victoria, B.C., the site chosen being on the crest of Gonzales Hill near the radio-telegraphic station and overlooking the Straits of Georgia. The Victoria Observatory is a branch of the Dominion Meteorological Service which has its headquarters in Toronto. There are in British Columbia about one hundred Climatological stations and the observers at these stations forward their monthly reports to Victoria, where mean values are computed and abstracts made for provincial use, after which the original records are forwarded to the Head Office in Toronto.

About fifteen years ago, it was decided to extend the forecast and storm warning service to the Pacific Provinces, and in view of the distance from Toronto, it was deemed expedient to have a synchronous weather chart prepared at Victoria and to issue the weather bulletins from that place. This provincial branch was placed under the supervision of Mr. E. Baynes Reed with Mr. F. N. Denison as chief assistant. About this same date a Milne seismograph was placed in Victoria, and Mr. Denison from the first evinced a most active interest in the records obtained and has during the past fifteen years charted all the wanderings and displacements of the pendulum, with the result that he now possesses seismological data of very considerable interest.

The new Observatory will be the Provincial Headquarters of the Meteorological Service and a complete equipment of the most modern seismological instruments will be placed in the basement.

THE INSTRUMENTS COMPRISE

Two Bosch-Omori Seismographs registering Mass 25 Kg. on smoked paper comprising the N-S and E-W components. Damping device.

Two Bosch Photographic Seismographs comprising N-S

and E-W components to include all the latest improvements as damping device etc. and special single filament electric lamp for 110 volt alternating circuit.

One Vertical Seismograph, Wiechert Type, smoked paper registration.

One special clock for making time marks on all Seismographs, is driven by weight, and regulated by a nickel-steel pendulum.

A little later it may be decided to place a transit instrument in the observatory and give time to the shipping of Victoria and generally throughout Vancouver Island.

The building is of concrete and with its dome will be one of the outstanding marks near the entrance to the outer harbor of Victoria.

Mr. F. N. Denison has been placed in charge of the New Observatory and of the forecast work of the Province, while Mr. E. Baynes Reed continues Chief Provincial Agent, with the care of all the climatological stations.

R. F. S.

ASTRONOMICAL NOTES

THE HISTORY OF THE CAPE OBSERVATORY.—In this work Sir David Gill has produced what might almost be called an epic of Astronomy. With much interesting detail he relates the growth, from the smallest beginnings, of an institution which is the foremost astronomical observatory in the Southern Hemisphere, and which by general consent ranks with the best of the national observatories of Europe. Every phase of the great expansion of astronomical knowledge and methods during the last century is touched on, for the observatory at the Cape of Good Hope, till comparatively recently almost the only guardian of the astronomical interests of the Southern Hemisphere, has neglected its charge in no branch of the science. For this reason its activities are more widespread than is now customary in first-rate observatories in the North, where specialization is increasingly the rule; whether in time to come it will be found well to adopt a similar policy at the Cape, when great observatories below the equator become more numerous, is for the future to decide, but there can be no two opinions on the soundness of the existing policy at the Cape under present conditions.—S. CHAPMAN, *Observatory*, No. 471.

A NEW ALGOL-TYPE VARIABLE STAR IN PEGASUS. R.A. $22^h\ 49^m\ 33^s$, Decl. $+32°\ 27'{\cdot}4$.—The reason why the star should have been seen so seldom below normal brightness is now obvious. The whole period of light change is only about $2^h\ 30^m$, and only during two hours of this is the star at all conspicuously below normal brightness, whilst the interval between two successive minima is very nearly five and a quarter days. Consequently it is only for two hours at intervals of twenty-one days that a single observer is likely to have the opportunity of seeing the star faint, and such an observer might indeed very well watch the star for several years pretty closely without once observing it during the two hours when it is at all conspicuously faint.—A. STAN. WILLIAMS, in *Monthly Notices*, R.A.S., No. 3.

THE LUNAR CRATER EIMMART.—In *Astronomische Nachrichten*, No. 4704, Professor W. H. Pickering calls attention to certain changes observed by him in the appearance of the crater

Eimmart. In the record of his observations on 15th January, 1913, he described what he saw as "a sea of cloud. As bright as the Apollonius region and larger. Brightness 9. The largest bright area visible upon the moon." Sketches are given for comparing the appearance with that observed on 9th August last, when the outbreak had ceased; the brightness was then 5, or a little less than the average of the brighter portions of the Moon. — *Journal British Astronomical Association*, January, 1914.

THE STUDY OF THE STARS.—The object of the American Association is the advancement of science. This is a very different matter from the diffusion of human knowledge. The universities and colleges provide liberally for the latter subject, but neglect the former almost entirely. Science is advanced by many individuals who hold offices in the universities, but seldom as a part of their official duties. Few professors are allowed to regard research as a portion of their college work, and still less frequently are appropriations made or funds provided for original investigation. Astronomy is almost the only exception to this rule, and even here in general, the time of the officers is mainly devoted to teaching. Observatories devoted to research like McCormick, Lick and Harvard are supported by funds given specifically for their use, and receive little, or no aid, from the general funds of the universities with which they are associated. It is probable that American universities devote one hundred times as much money to the diffusion of human knowledge, as to its advancement. The great progress made in America in some departments of astronomy is due to the fact that certain wealthy men and women have been willing to give large sums of money for this object. No other country is so fortunate in this respect, although in recent years in Germany large appropriations are being made by the government for similar purposes.

One of the greatest needs of science in America is a fund of moderate size, capable of aiding the men of real genius. The number of such men is not large, and a judicious distribution of a few thousand dollars annually would probably yield greater results than could be obtained in any other way.—From President's Address, American Association for the Advancement of Science, 1913, (Edward C. Pickering).—*Popular Astronomy*, Vol. XXII, No. 2. J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

Query

Can you explain the physical process by which the temperature at a place is changed many degrees in a few hours? Recently in Toronto there was a sudden drop to − 22° F., and then within 24 hours the temperature rose to 34° F., a change of 56 degrees. Does the air actually travel from one part of the continent to another?—E. H. C., Toronto.

Answer

By the Director of the Meteorological Service:

The low temperature which occasionally occurs in the more southern part of this Dominion, and in fact in the lower latitudes generally, is due to the southward movement of air from higher and colder latitudes. The coldest zone in this continent is near the Arctic coast, this being a fact verified by observation and in accord with the assumption that the intense cooling of northern lands in winter in these latitudes is wholly due to radiation, at the surface of the earth.

Whilst it is possible to trace the sequence of events which lead to the transference of a cold wave across the country, the factors which lead to the formations of areas of high and low pressure are not so apparent.

The problem of the varying distribution of atmospheric pressure in corresponding seasons of different years has not yet been solved, hence we cannot say why northerly winds should be prevalent in some years and not in others.

R. F. Stupart.

Query

During the opposition of Mars in 1907 the weather for weeks was cloudy and rainy. The same thing occurred in 1911 and at that time the writer wondered if it would occur in 1913-14. As it is doing so, is there any connection between the planets and the weather, and does Mars in some manner affect our climate, more particularly when relatively close? The whole may be merely an odd co-incidence, but again there may be some known or unknown reason. I have often wondered about it.—H. W., Guelph.

Answer

I believe no connection between the positions of the planets and the nature of the weather has ever been demonstrated.

THE ANNUAL MEETING OF THE SOCIETY

The General Annual Meeting was poorly attended, the temperature at the time being about – 18° F., but the General Secretary informs me that the reports from the various Centres were received in better form than ever before. In some instances, however, there was a slight lack of co-operation, which arose evidently from a misunderstanding of the proper mode of procedure.

The General Annual Meeting should receive reports from all the Centres, and these should include a review of the past year's work, the local treasurer's report, and also an estimate of the expenses for the next year. With all the information before it, the meeting should then approve appropriations for the various services for the next year. The General Council should look after the expenditures under the appropriations.

It is evident then that each Centre should have its annual meeting early in December, at which the reports to be sent to the General Secretary should be passed. These should form a basis for action by the General Meeting for next year. This procedure was followed in some cases and it is highly desirable that it should obtain in all.

HIGH COSMIC VELOCITIES

The orbital velocity of our earth is on the average about 18½ miles, or nearly 30 kilometres, per second, while Mercury when at perihelion moves at the rate of almost 58 km. per second. Most of the stellar velocities, determined by the spectrograph, are of the same order as these, but recently some notable exceptions have been discovered. Campbell, in his "Stellar Motions," (as already stated on an earlier page of this issue) gives the following velocities in space for three particular stars:

Groombridge 1830 ..... 250 km. per second
Cordoba Zones 5h·243 ..... 260 km. per second
Arcturus ..... more than 150 km. per second

From the Lick Observatory and its southern station are reported the following:

Nebula No. 4846, 2nd Index to N.G.C., R.A. 19h. 11m·0, Dec. 19° 14′, 10th Mag. .... + 165 km. per second

Planetary Nebulæ N.G.C. 5873, R.A. 15h. 0m·3, Dec. − 37° 43′ ..... − 133 km. per second

At the Mt. Wilson Solar Observatory Messrs. Adams and Kohlschütter obtain for

Star Lalande 1966, R.A. 1h. 3m·3. .... − 325 km. per second

The spectral type is *F*, and the parallax is 0″·08 or its distance is 40·8 light years.

This velocity is remarkable, but Dr. V. M. Slipher, of the Lowell Observatory, gives still more extraordinary results.

For Great Andromeda Nebula ..... − 300 km. per second

For N.G.C. 1068, 4565, 4594 and certain other spirals ..... about 1000 km. per second

Dr. Slipher also finds that the spectrum of H V 30 is peculiar, containing only hydrogen lines, the "nebulium" line, hitherto considered the essential constituent of a nebular spectrum, being absent. These remarkable results must lead to a modification of some of our views regarding the stellar universe.

DR. WATSON'S VOLUME OF POEMS.

Readers of the JOURNAL will recall several poetical contributions which have appeared in its pages during the last few years, particularly the monologues "Copernicus" and "Galileo" printed in 1913; and will not be surprised to learn that Dr. A. D. Watson, their author, has published a volume of verse. Indeed this is not his first appearance as an author.

The volume is entitled "Love and the Universe," contains 190 pages and bears the imprint of the well-known publishers, The Macmillan Co.

Dr. Watson is one of Toronto's best-known physicians, is first vice-president of our Society, of which he has long been a member, and is prominent in efforts aiming to improve the social condition of our city. As we might expect, we find in his poems evidences of these various activities. Throughout we feel the author's thoughtful and serious interest in that which is really worth while and abiding in life, and there is ever present the inspiration which comes from close contact with nature — "free space," the "open sky," "God's great atmosphere," or from being

> "Companion of the mountain
> And comrade of the sea."

The first portion of the book consists of miscellaneous pieces, the longest being the first, which gives the name to the volume. Four poems in this part deal with astronomical subjects, namely, "The Comet," "Kepler," "Northern Lights," "The Wonder Star" (Mira), while many others bear evidence that the author is a keen observer of natural phenomena. Amongst the latter, that which pleases me most is a sonnet, entitled "God and Man," of which the last six lines are:

> "A light that twinkles in a distant star,
> A wave of ocean singing on the shore,
> One substance with the sea; a wing to soar
> Forever onward to the peaks afar,
> A soul to love, a mind to learn God's plan,
> A child of the eternal — such is man."

Of the astronomical pieces the description of the quick motion and shimmering appearance in "Northern Lights" is very apt. The sonnet is as follows:—

"Weird armies wave their scimitars of light,
And sabres glimmer in the cloudless deep
While up the ebon battlements they sweep
With shimmering steel exultant to the fight.
They charge, contend, retreat with sudden flight,
Then press again the battle up the steep,
Till all the northern skies with lances leap
Around the flaming coronal of night.

But soon the legions with their splendors fade;
Each bright battalion in the lofty arch
In midnight's scabbard sheathes his blood-hued blade;
The ranks from zenith to horizon march,
And where was camp and panoply of Mars
Is sable night, pierced by the jewelled stars."

The second portion of the book consists of twenty-six monologues in which the author makes various great historical personages speak their own views on life. This kind of writing requires the author to project himself into the life and time of the person speaking and so is a difficult kind of composition. I believe, however, this is the most successful feature of the book, and the author is to be congratulated on his excellent work. The two monologues, "Copernicus" and "Galileo," already referred to, are good examples of Dr. Watson's ability to appreciate the characters he brings before us.

THE POETS AND THE MOON

The book of poems just discussed is from the hand of a real observer and consequently his references to natural phenomena are accurate. But I have lately come across a couple of examples of the opposite state of affairs.

In a recent number of *Nature* a correspondent quotes from a poem entitled "Early one Morning" which appeared in *The English Review*, as follows:—

Have you heard what the young moon said to me
As I walked in the morning early?

. . . . . .

She lay on her back and laughed at me
As I walked in the morning early.

The other case is not so glaring as this; the author simply does not recognise the fact that 'myriads' of stars cannot be seen when the full moon is overhead in the sky. In a Toronto journal appeared recently a review of the book of verse referred to, and in illustration of the author's work a sonnet was quoted which contained the following:

"For o'er him bends the lovely dome of blue,
Agleam with myriad stars; while silently
The glorious orb of night is sailing through
That sea of light, all pure, serene and free."

It may seem almost hypercritical to refer to this, but ours is a scientific age and we are always displeased when speakers or writers use illustrations which we know are not strictly true.

OBSERVATIONS OF THE PLANET MERCURY

During the month of February the planet Mercury has been very well placed for naked-eye observation. On seven evenings it was seen by the present writer, and many of his friends were also able to find it.

C. A. C.